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China Ecosystem Services and Poverty Alleviation Situation Analysis and Research Strategy

Final Report

Submitted to:
NERC, ESRC and DFID

23 May 2008

Chinese Academy of Agricultural Sciences (CAAS)
CAB International
UNEP World Conservation Monitoring Centre
Stanford University - The Natural Capital Project
Walker Institute for Climate System Research, University of Reading
Ningxia Centre for Environment and Poverty Alleviation
Ningxia Development and Reform Commission

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Executive Summary

This report, commissioned by NERC/ESRC/DfID, presents key findings in four sections of a situation analysis and research strategy for ecosystem services and poverty alleviation in China.

Section A summarises knowledge on poverty and ecosystem services. In 2006 there were approximately 80 million people in China below the $1 per day income level. Most of the poor are in west and central regions, and poverty is particularly prevalent in mountainous and grassland areas. Many factors contribute to poverty, including low agricultural productivity and degraded ecosystems, with natural disasters consistently reported as a major cause.

A characteristic of China's land use is of many people on limited farmland, which occupies just 14% of the country and 367 million hectares are susceptible to soil erosion. Grassland ecosystems have the most extensive land cover (41%), predominantly in western China and Inner Mongolia. Grassland degradation has been recorded over 135 million hectares, with an annual increase of 2 million hectares. Desert ecosystems cover about 13% of China and have been increasing by about 200,000 hectares per year. Forest ecosystems are mostly in the south and northeast, less than 5% of which are primary forest, but plantation area is rapidly expanding. Wetlands occupy 3.8% of the territory, but more than 50% of them have been transformed to cropland during the past 50 years. This study classified China into eight ecological zones to guide the definition of poverty alleviation and ecosystem management strategies. The risk of poverty due to intrinsic ecosystem properties was assessed as high in the Loess plateau, Qinghai-Tibetan plateau, the northwest arid region, the north grassland and the southwest Karst region, all of which have serious soil erosion problems and low biotic productivity.

Key findings from the literature on China's ecosystem services and poverty linkages include:

Provisioning services - Agriculture constitutes 70-80% of the income in western China, and it is estimated that 20 million people in this region live in poverty due to a lack of water and suitable agricultural land. Irrigation is a key means of increasing production. Poverty levels amongst grassland-dependant people are 41% in Xingjiang, 35% in Qinghai, and 18% in Inner Mongolia. It is estimated that 200 million people in China currently have no easy access to clean drinking water and that 47% of the population is water stressed. Restrictions on harvesting timber have made non-timber forest products (NTFPs) in many regions more important to the economy than timber.

Regulating services - Soil erosion is approximately 5 billion tons per year. On average, floods affect more than 100 million people annually. Forested land acts as a major carbon sink in China, but degradation has transformed grassland soils into a net carbon source, emitting 3.56 Pg SOC. There is a lack of information on the contribution of grassland to erosion regulation.

Supporting services - There is little available information on nutrient cycling and soil formation services in China, despite their fundamental importance to agriculture and water quality.

Cultural services - Although China is extremely culturally diverse, there is very little available information on cultural ecosystem services.

Many of the provisioning and regulating ecosystem services in China are either in decline or increasing at a rate slower than demand. Despite the considerable ecosystem services of wetlands there is very little published information on their importance to the poor. The majority of available information on ecosystem services in China is for the provisioning services. However, various valuation studies have put regulating and supporting ecosystem services at a higher value than the provisioning services.

Section B examines decision-making and drivers of change for ecosystems and poverty. China's population of 1.32 billion in 2007 is now forecast to total 1.47 billion in 2050, 382 million (26%) of which would be in rural areas. China's average real GDP growth rate of 9.75% in 1979-2006 is a major driver of both poverty reduction and demand for ecosystem services, but with major pollution impacts. Migration of labour from western to eastern China has contributed to poverty reduction and reduced pressures on local ecosystems in western China. One study estimated that strengthened land tenure could stimulate 200 million households to invest in soil and water protection. Research on strengthening property rights is needed for developing Payments for Environmental Services (PES) with positive impacts on poverty.

China now has a comprehensive and rapidly developing system of legislation, strategies and programmes for addressing ecosystem restoration, poverty reduction and sustainable development. Government projects are often very large scale and have produced major progress in their sectors, but more research is needed on their impacts on poor people and ecosystem services, including the ecological processes such as water and mineral cycling that underlie their sustainability. Greater involvement of the poor in policy design is also required. Improving ecosystem management for poverty reduction requires an inter-disciplinary and systems focus, with more 'joined up' policy making and learning from successes and failures. This is linked to the need for China's successful science and technology development to develop a new focus and capacity for management of ecosystems for multiple types of services to reduce poverty.

Although extensive ecosystem valuation studies have been done in China and many PES and other eco-compensation schemes are being implemented, the two are rarely linked. This situation analysis found that human-induced climate change will impact on China's ecosystems, species, carbon storage, water resources and crop production. The precise impacts vary with different models and climate scenarios, but on the whole are either negative or neutral. Impacts on livelihoods are expected to range from gradual changes in crop productivity and distribution of suitable zones, to dramatic impacts from more frequent flooding and drought. China also faces a significant challenge of invasive alien species negatively affecting ecosystem functions and potentially increasing poverty. This problem is worsening with expanding global trade and transportation systems.

Section C identifies challenges and research needs for ecosystem services and management to alleviate poverty in China. These findings are drawn from the situation analysis, a case study of Ningxia province, and consultations with the project's Advisory Committee. Some 50 key research needs have been identified and categorised according to poverty, ecosystem services, drivers of change and major policies and programmes, valuation of ecosystem services, pollution, potential impacts of climate change and IAS, and cross cutting issues. The priority cross-cutting issues are:

- Identification of the inherent characteristics and relationships between ecosystem services and poverty alleviation at the regional scale.
- Understanding of how ecosystem functioning becomes degraded, particularly for shortages of water provisioning and regulating ecosystem services.
- Exploration of effective soil and water management to support poverty reduction needs and productive ecosystems.
- Evaluation of the impacts of climate change on ecosystem services and regional adaptations of the practices of agricultural production to climate change.
- Evaluation of ecosystem response and resilience to invasive alien species, and the impact of invasion on native ecosystems and their associated ecosystem services.
- Development of management mechanisms to incorporate ecosystem services into poverty alleviation strategies, promoting integrated and whole-system perspective management.
- Exploration of an innovative knowledge and information extension system for the uptake and utilisation of ESPA research results.

Section D is a capacity development strategy for research providers and users, based on knowledge gaps and skills needs identified through questionnaires, semi-structured interviews and literature reviews. Training, building partnerships and information exchange mechanisms are required to improve understanding and knowledge of ecosystems services and poverty linkages, particularly between natural sciences and social sciences, with a policy focus.

Acknowledgements

First and foremost, we wish to highlight that this important study would not have been initiated and carried out in its full depth and breadth without the intellectual, moral and financial support of NERC-ESRC-DFID. In particular, we wish to acknowledge the foresight and the assistance of the Director of Terrestrial and Fresh Water Sciences Division of NERC (Dr. Pamela Kempton), the Science Programmes Officers of NERC (Dr. Caroline Culshaw and Dr. Katie Waiters), DFID China office (Dr. Elizabeth Wilson) and Research Councils UK China Office (Dr. Carol Rennie).

We wish to express our sincere gratitude to the members of the Advisory Committee for their valuable comments. Specifically, the assistance that they provided in guiding and scrutinizing the early work and results has significantly contributed to the comprehensiveness and quality of this study. In addition to this, we also wish to express great appreciation to our consortium members and colleagues who acted as implementers, authors, reviewers or editors in the ESPA China situation analysis project, and to their institutions as well for supporting their participation.

We would like to express our sincere thanks to the Ningxia Development and Reform Commission and the Ningxia Centre for Environment and Poverty Alleviation for offering and assisting in a highly relevant and significant project case study which showcased considerable and valuable information at the provincial level.

Last but not least, we thank the Department of International Cooperation of Ministry of Agriculture and Department of International Cooperation of Chinese Academy of Agricultural Sciences for their help in supporting and facilitating the smooth running of our meetings and work plans.

China Ecosystem Services and Poverty Alleviation Situation Analysis and Research Strategy

Introduction

In 2005, the Millennium Ecosystem Assessment showed that the loss of goods and services from ecosystems (e.g. food, timber, soil formation, water purification) is a significant barrier to reducing poverty, hunger and diseases. Tackling this set of problems requires an interagency and multidisciplinary approach drawing on a combination of environmental science, ecological economics and political economics.

Three UK organisations, the Natural Environment Research Council (NERC), the Economic & Social Research Council (ESRC) and the Department for International Development (DfID) have come together to explore the potential for a multi-disciplinary research programme that will address how to achieve sustainably managed ecosystems for poverty alleviation. The Ecosystem Services and Poverty Alleviation (ESPA) Programme is in a design phase, running through 2007 and 2008. Four regional and two thematic studies have been commissioned. The study for China was conducted in parallel with other studies for India Hindu Kush Himalaya region, semi-arid regions of sub-Saharan Africa, the Amazon and its Andean catchment, urban/rural interactions, and a marine and coastal assessment.

The aims of this China study were to conduct a situation analysis on the knowledge of China's ecosystem services and their importance to the poor, identify and address challenges to the sustainable management of ecosystems for poverty alleviation, and propose a research strategy to inform the design of a five-year, multi-disciplinary ESPA research programme. Whilst the study is designed to meet the needs of the ESPA Programme its results can also contribute to ecosystem management and poverty alleviation research and policies in China.

The study has been conducted by an international consortium led by the Chinese Academy of Agricultural Sciences (CAAS) in collaboration with CAB International (CABI), UNEP-World Conservation Monitoring Centre, Walker Institute for Climate System Research of Reading University, Stanford University - the Natural Capital Project, Ningxia Development and Reform Commission and Ningxia Centre for Environment and Poverty Alleviation. The study involved work in four stages and a total of 23 work-packages (see Annex 1 for the project methodology). Consortium partners led specific work-packages based on their areas of expertise. The outputs of work-packages included a literature review, a case study from Ningxia province (see Annex 4), and semi-structured questionnaires and interviews. Consultations were also done with relevant stakeholders and the Project Advisory Committee. A website was created to support overall project management, communications (including publicity and awareness-raising) and information management, exchange and sharing.

The situation analysis covered the whole of China. In view of the vastness of China and the short time-frame for the work, the study adopted a broad brush but comprehensive approach to synthesise existing information. Whilst the study covered the entire country it has a geographic focus on western China, where the majority of China's poor are found and the ecosystems are most sensitive to change. The study's main findings have also been enhanced with a more detailed analysis of the Ningxia Autonomous Region as a specific case study.

The main report is presented as four major sections corresponding to the study's objectives. The four sections are: (a) Status of poverty and ecosystems in China, (b) Decision-making and drivers of change for ecosystems and poverty in China, (c) Challenges and research needs for ecosystem services and management for poverty reduction in China, and (d) Capacity development strategy for research providers and users to maximise sustainable ecosystem management for poverty alleviation in China. A number of useful annexes, such as a glossary, project methodology, conceptual framework, references, and Ningxia case study details are provided to supplement the main sections. The term ESPA has been used in the report to refer to research on the subject of ecosystem services and poverty alleviation.

Section A: Status of Poverty and Ecosystems in China

Section A presents a summary of the state of knowledge and principal issues in China regarding poverty, ecosystems and ecosystem services, concluding in Section A4 with reported linkages between these topics. Please see Annex 2 and Annex 3 for an explanation of the conceptual framework used in this study and definitions of ecosystems, ecosystem services and ecosystem management in relation to poverty reduction.

A1 – Poverty in China

Poverty definitions

The most widely used definition of poverty in China is the rural poverty line calculated by the National Bureau of Statistics (NBS) (Wang and Li, 2005). This was first calculated in 1985 as RMB 200 yuan income per capita per year, as the threshold for the purchase of goods and services for the minimum requirements of living and calorific intake (Tang, 1994). The rural poverty lines in 1985, 1990, 1994 and 1997 were calculated based on the Rural Household Survey, and in other years were updated on the basis of adjusting the Consumer Price Index in the rural population. In 1997 the poverty line was RMB 630 yuan. In order to better monitor poverty and anti-poverty policies, and to facilitate international comparisons, the NBS has also calculated a national low-income line since 1998. In 2007 the poverty line was RMB 683 yuan and the low-income standard was RMB 944 yuan.

In 2007 the China Development Report of the China Development Research Foundation has recommended that the government raise the poverty line to RMB 1,100 yuan, to include basic expenditure on health and medical expenses in the calculation. This standard would result in 80 million people classified below the poverty line, rather than the current 23 million.

Whilst China's poverty line is based on meeting basic needs the concept of poverty is also widely recognised as being multidimensional, including the dimensions of lack of opportunity, low capabilities, low levels of security, and empowerment (World Bank, 2002). However, in China most of the poverty research literature focuses on largely economic measures of poverty as reflected by the poverty line definition, with most studies examining the relationship between economic growth and poverty reduction or the inequality issue between regional or rural and urban areas (Chen 2006, Liang 2006, Lin 2006, Wang 2006, Wan 2006, 2007, Zhang 2005 2006a 2006b).

In order to compare poverty conditions among counties, the World Bank studied their national poverty criterions in 1990, and adopted the 370 US dollars as a general international poverty standard to measure each country's poverty conditions. Soon the poverty standard of the annual 370 US dollars calculated, at purchasing power parity in 1985, was be simplified into a "one dollar one day" poverty standard, and was widely accepted (Wang, 2007). Compared with World Bank poverty line, the Official Chinese poverty line of RMB 625 yuan measured by annual per capita income in 2000 seems not only far less than 1 US dollar per person per day set by the World Bank, at purchasing power parity in 1985, but also less than the poverty standards in many Asia countries such as Indonesia, Philippine, Thailand, Malaysia, etc. However, Official Chinese poverty line is reasonable, which was set on the base of China's government fiscal capacity and budget limitation of the poverty-alleviation programs. It has been proved that the implementation of poverty alleviation policies addressing to the population living below the poverty criterion is effective.

Rural poverty

Since the end of the 1970s poverty reduction in rural China has been a remarkable achievement. The number of rural poor as measured by the official poverty line reduced from 250 million in 1978 to 21.48 million in 2006, with a decline in poverty incidence in the rural population from 30.7% to 2.3%. However, the rate of poverty reduction has slowed since about 2000 (Figure A1.1). It is estimated by Malik (2007) that the number of people living on less than $1/day in China has fallen by over 400 million since 1981, while $2/day poverty declined by 300 million. If poverty were measured in line by the international definition of $1/day income the poverty-stricken population in China would be 80-100 million in 2006. The lower poverty line of the Chinese government is considered to provide an objective basis for the government to concentrate poverty alleviation resources, to support poor rural people who haven't meet the basic food and clothing needs, implement socio-economic development measurement and carry out relief and disaster-relief work to the extreme poor population. The Gini

coefficient of income inequality for rural residents in 2003 was calculated as 0.368 and for the whole nation as over 0.4 (Xian, 2004). China has reduced income poverty in rural areas probably faster than any nation in human history. During the transition from a centrally-planned to a market-based economy and in the process of modernization, China has accomplished the twin tasks of economic growth alongside with poverty reduction.

Urban poverty

Although this ESPA study focuses on rural poverty it should be noted that according to survey statistics China's urban poverty population should be between 15 million and 18 million, but viewpoints shared by most scholars consider China's urban poverty population should be over 30 million, and if migrant workers from the countryside are included China's urban poverty population could be 50 million.

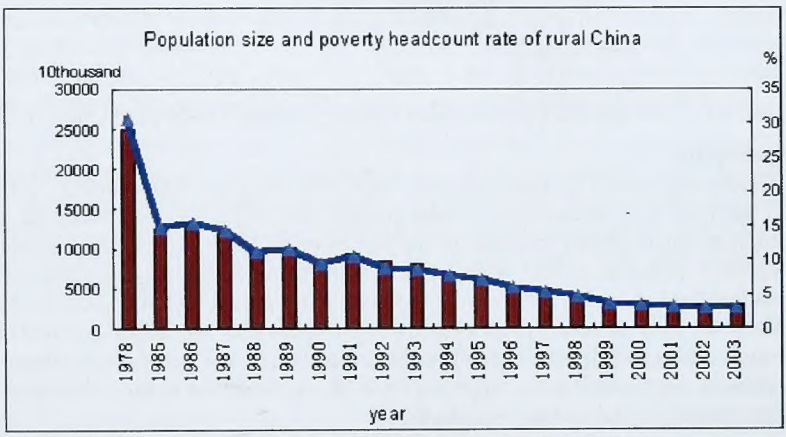


Figure A1.1 Population below the poverty line in China.

Distribution of poverty

Poverty levels are highest in western China (Table A1.1) and are above 10% in Qinghai province and between 5% and 10% in western provinces such as Inner Mongolia, Guizhou, Yunnan, Tibet, Shannxi, Gansu and Xingjiang. Absolute poverty in the western region is estimated to affect over 30 million people taking the definition of $0.75 a day; a figure that would rise to 100 million taking the below $1 a day poverty line (Berry, 2003). Other estimates have placed the number of people in poverty in the 12 western provinces at 17 million (Yanlin, 2004). Poverty is particularly prevalent in mountainous areas where 12.28 million poor people live, which is 51.9% of the total poor population, including pockets of poverty in the mountainous areas of the coastal provinces (Liu, 2006).

TableA1.1 Poor population and impoverishment rates in China (Source: RSDNBS 2006)

	Poor population (million)	*% of total rural poor population*	*Impoverishment rates (% of total population)*
Eastern Region	1.42	6.0	0.4
Central Region	6.68	28.2	2.4
Western Region	14.21	60.1	5.0
Northeast Region	1.34	5.7	2.4
Total	23.65	100	2.5

Since 1984 the Chinese government has focused its poverty reduction policies on counties with concentrated poor populations, which are now called "Key Poverty-Stricken Counties", based on per capita net income thresholds. In 2001 there were 592 such counties, spread over 21 provinces (autonomous regions and municipalities), with the majority in Central and West China, but none on the coast (Figure A1.2), and covering 62% of the total rural impoverished population in China.

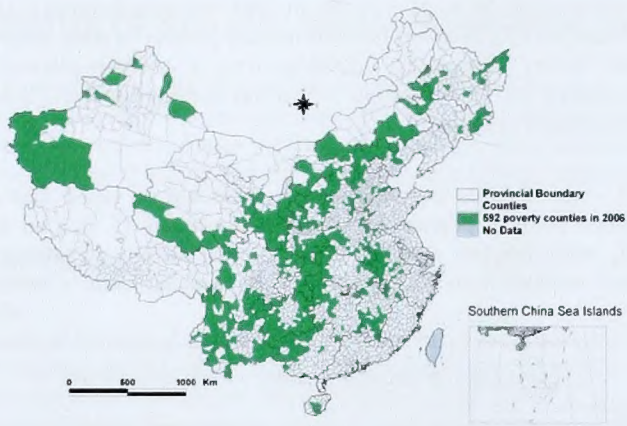


Figure A1.2 The distribution of the Key Poverty-stricken Counties in China in 2006.

Causes of poverty

The main factors attributed to rural poverty in China include harsh natural conditions, poor infrastructure facilities and limited social development. No single cause is likely to be found in a particular situation. Shen (2004) considered that in western China high poverty levels were due to growing population pressure, a low level of development, and serious ecological degradation. In western China fertility-led rapid population growth and grain production at or below subsistence level up to the 1980s not only slowed the process of industrialization and urbanization, but also caused severe land and ecological degradation through deforestation and farming on slopes. Other than population pressure, weak economic competitiveness also contributed to the substantial development gap among the eastern, central and western regions.

A survey in 2006 of 4,041 poverty-stricken households in 72 villages across the country found that low returns from crops (72% of respondents) was reported as the major reason for their poverty, with growing expenditure on healthcare and children's education the other main causes (CDRF, 2007).

Natural environment

Heilig et al. (2006) concluded that geographical and ecological conditions are often responsible for the persistence of poverty in China. The productivity of ecosystems and the supply of services that they can provide are fundamentally determined by the climate-soil-vegetation combination. These factors depend on relative location to the temperate zones and monsoon zones in China and altitude. Frequently the climatic factor of drought is a critical cause of poverty in northern China, which can be worsened by ecosystem degradation. Steep slopes and soil erosion are critical factors for poverty in southern China. The intrinsic properties of ecosystems in China in relation to the risk of poverty are further analysed in Section A2.

In 2005, more than 50% of the impoverished population lived in mountainous areas, and 76% of the chronic impoverished population lived in remote mountains, rocky land, high cold mountain areas, and the Loess Plateau (Liu, 2006). Mountainous areas comprise 496 of the 592 official poverty counties in 1996 (Miao and West, 2004), 383 of which are located in western China (Tan and Guo, 2007). Heilig et al. (2006) conducted a GIS analysis of poverty and non-poverty counties in China, which confirmed that most poverty counties are found in mountainous areas. More than 69% of the area in poverty counties, on average, is covered by slopes with more than 15 degrees, versus 29% in non-poverty counties. The average altitude of poverty counties is three times higher than that of non-poverty counties (1633 metres compared to 566 metres), with a correspondingly cooler climate. These areas are lacking in infrastructure for transport and information exchange, and are typically dominated by ethnic groups (Tan and Guo, 2007).

Most poverty-stricken poverty counties are located in the areas with low ecosystem productivity and supply of services. In 2005, in all the state poverty-stricken counties, 67% had dry arable land, 24.6% without irrigation and 34.3% without paddy fields (RSDNBS, 2006).

Social causes

In general, the impoverished and low-income population have lower education and human capital. The

enrolment rate of children in the key poverty-stricken counties was far below the nine-year compulsory education standard. Compared to the other counties, the poverty-stricken counties lag behind 20 years in respect of the rural health service, the social security system is underdeveloped, and financial capital is lacking.

Heilig et al. (2006) also found that ethnic and cultural factors are correlated with persistent poverty in China, with the average minority population in poverty counties four times higher than in non-poverty counties.

Economic causes

A critical factor in the maintenance or reduction of poverty is the location of people in relation to economic and market factors. These include distance to large cities, seaports, border development zones, or distance to major highways and emerging express highways, and railroad linkage to outside world. China has a major infrastructure development programme to improve linkages and trade between its regions and internationally. Government development policy has dramatically affected regional economic growth in China since 1978, such as the rapid development of special economic zones, seaports, border cities, railroad stations, river ports, and capital cities of all levels.

Wang and Cai (2006) found that rural to urban labour migration on an unprecedented scale played a vital role in rural income growth, poverty reduction and economic development. They also concluded that China's rapid economic growth, averaging 10% per year, has ensured the country's large reduction of rural poverty, especially during the earlier reform period. Slow agricultural growth and rising income inequality in rural areas, however, are factors that weaken the effects of economic growth on rural poverty reduction.

Natural disasters

People who have moved out of poverty are still vulnerable to return to poverty from natural disasters, with 66% of poverty-stricken villages subject to different types and levels of natural disasters, with subsequent declines in agricultural output (Li, 2006). In 2005, in all the state poverty-stricken counties, 41.1% were suffering from serious natural disasters (RSDNBS, 2006). According to the government poverty monitoring survey (Xian, 2004), natural disasters have become the main cause of poverty in China, with 55% of households falling into poverty doing so due to serious disasters such as drought and flood.

A2 – Ecosystems of China

Terrestrial China is very rich in biological diversity and contains almost all the types of major ecosystems of the northern hemisphere. China's ecosystems are first described according to functional categories of land use and land cover, and then by regions or zones based on similarity and differentiality.

Major types of ecosystem

According to the main land use or land cover pattern, ecosystems in China can be classified into five major types: cropland, forestland, grassland, arid land (desert) and wetland. Figure A2.1 and Annex 5 show the spatial distribution of these five major ecosystem types in China. Different classifications and survey methods have produced slightly different results of land use and land cover change in China, but with overall consistent findings. Ren et al.(2007) report the land cover of the country's five major ecosystems as farmland 13.9%, forestland 18.2%, grassland 41.6%, arid land and unused land (mainly desert) 22.0%, and wetland 1.9%. Results of the National Land Use Survey in 1996 and remote sensing data from 2005 (CSB, 2006) are presented in Table A2.1, which shows a significant increase of 8.13 million ha in forest and decreases of 3.96 million hectares of pasture and 7.96 million hectares of cultivated lands. The increase in land for China's rapidly expanding transportation network is also noteworthy, as this reduces the supply of ecosystem services not only through the reduction in ecosystem extent, but also by fragmenting large areas of natural land and altering ecosystem processes such as water flows. No data was found on ecosystem fragmentation and effects.

Table A2.1 Land use change in China (Source: CSB, 2006)

Land use categories	Year 1996 (1000ha)	Year 2005 (1000ha)	Change (1000ha)	Growth rate	Change of share by %
Total area	**950680**	**950680**	**0**	**0.000**	**0.000**
Forest land	227610	235740	8130	0.036	0.855
Residential land and mining ground	24080	26020	1940	0.081	0.205
Tree crops land	10020	11550	1530	0.152	0.161
Transportation land	1650	2310	660	0.398	0.069
Other agricultural land	25300	25530	230	0.009	0.024
Water conservancy facilities land	3520	3600	80	0.023	0.009
Unused land	262390	261710	-680	-0.003	-0.072
Pasture land	266060	262140	-3920	-0.015	-0.413
Cultivated land	130040	122080	-7960	-0.061	-0.837

The general land-use characteristic of China is one of many people on limited farmland, lack of natural resources, and a large demand for construction land. This land situation is one of the main factors that constrains the steady growth of grain production in China and sustained and healthy development of the national economy (Lu, 2001). China's per capita arable land is 0.106 hectares, per capita forest is 0.186 hectares, and per capita grassland is 0.217 hectares, which are respectively equivalent to 44%, 18% and 35% of the world average. China's land resources distribution is uneven and particularly does not match the regional distribution of water resources, which seriously affects land productivity. The area of the Yangtze River Basin and to the south has more than 80% of the total water resources of the country but only has 38% of the total cultivated land area, while the area of the Huai River and to the north has less than 20% of the country's water, and 62% of its arable land.

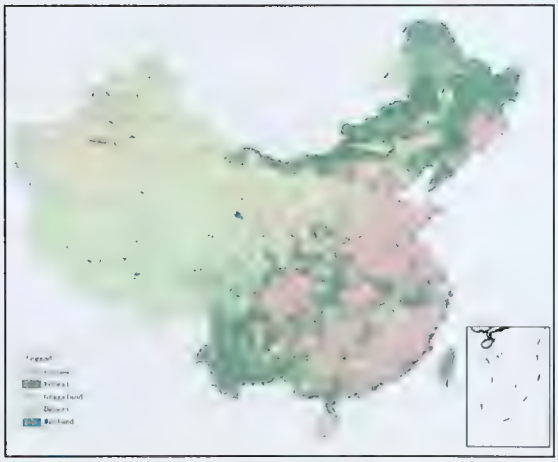


Figure A2.1 Spatial distribution of five major ecosystem types in China (Source: Liu, 1998)

Cropland ecosystems

The main cropland ecosystems in China, in terms of both economic production and ecological functions, are rain fed cropland, irrigated cropland and paddy rice field. Total acreage of cropland in China was estimated at 1.33 billion hectares in 2006, accounting for 13.9% of the total land area (Ren et al., 2007). The farmland ecosystems of China are very diverse, ranging from paddy farms in southern China to dry farmland in western China (Zuomin, 2003). Total irrigated land in 2000 was 53.9 million hectares (Zhou, 2002). Soil erosion occurs over 367 million hectares or about 38% of the land area, with an annual increase of 1 million hectares. A large proportion of cropland (approximately 560 million hectares) has been seriously degraded from the excessive use of organic fertilisers, chemicals, industrial pollution, heavy metals, acid rain, and rapid expansion of village and town industry (Desertification Prevention and Cure Office in China, 2003, in Ren et. al., 2007). Cropland in the north and northwestern regions is seriously threatened by salinisation and alkalised soil. Moreover, about 40,000 hectares of land is taken up by the construction of industry and town development every year (Ren et. al., 2007). Cropland ecosystem degradation contributes to the frequent drought and flood disasters every year. Natural disasters damaged about 100,000 hectares of arable land each year. By

1996, mining had destroyed 2.8 million hectares of land, whilst the mining land reclamation rate was only 12%. Details of changes in cultivated land area are included in Annex 7.

Forest ecosystems

The main forest ecosystem types are temperate coniferous forest, temperate broad-leaved and mixed forests, subtropical broad-leaved and coniferous forests, and tropical monsoon and rain forests. Although the total land cover occupied by forest including shrub land is 2.58 billion hectares, the actual forestland is only 1.75 billion hectares, and primary forest accounts for less than 5% (Ren et. al., 2007). The distribution of China's forest is very uneven, with the majority in the south and northeast of the country. In recent years, the total land cover occupied by plantation has increased to 0.53 billion hectares, particularly due to the construction of shelter forest in the upstream Yangtze River and the 'Three North Shelters'. However, the quality of forest has seriously decreased due to loss of primary forest, afforestation with exotic species, and creation of monocultures in forest ecosystems (Ren et al. 2007, Shen 2005). Non-degraded forest area only accounts for 28% of the total. Forest degradation has also accelerated soil and water erosion problems and biodiversity loss.

Grassland ecosystems

Grassland ecosystems have the most extensive land cover in China, with about 3.99 billion hectares (41.6% of total land), 2.78 billion hectares of which are concentrated in the western region of China. Of the total grassland area 49.2% are pasturing areas, 14.9% are half agriculture and half-pasturising areas, 30.8% are agriculture and forest stand areas, and 5.1% are found in lake, river, and coastal belts (Ren et al, 2007).

Various types of grassland degradation have been recorded over 135 million hectares, with an annual increase of 2 million hectares in recent years. The grassland in Inner Mongolia's prairies, Loess plateau and southern Xinjiang and Qinghai suffer from wind erosion and low vegetation coverage. The grassland ecosystems in the northwest suffer from desertification; and the grasslands in Yunnan, Guizhou, and the Qinghai-Tibet plateau face severe water and soil erosion. Major reasons for grassland degradation include overgrazing, over consumption of medicinal plants and forest resources, conversion to crop land, the expansion of mining and industrial projects, and rodent and insect pests (38.94 million hectares grassland suffered from rodent plagues and 17.58 million hectares suffered from insect pests). Estimates put levels of overgrazing at 130% above carrying capacity in Shaanxi, and 250% in Ningxia (SEI and UNDP, 2002).

Wetland ecosystems

The wetlands of China, including swamps, lakes, and rivers, account for 10% of the world's total wetland area. Natural wetlands occupy 3.8% of China's land and are unevenly distributed among eight wetland regions. More than 50% of wetland area has been transformed into farmland in the past 56 years in order to grow crops (State Forestry Administration of China, 2000). Similarly, more than 50% of the coastal wetland area of China was transformed for agricultural, urban, and industry purposes (State Forestry Administration of China 2004, Ren et al. 2007). With increasing population pressure and rapid economic growth, wetlands have been over-exploited in China, which has resulted in a sharp decrease in extent and deterioration of their ecological functions.

Arid land (desert) ecosystems

The total area covered by desert ecosystems is about 1.28 billion hectares (13.3% of China). The Gobi desert in the north of China accounts for 0.57 billion hectares (5.9%) of the country. The Takelamagan desert, located in the Talimu Basin in the southern Xinjiang province, is the largest desert in China and the second largest flowing desert in the world. China's desert is increasing at rate of 2,100 km^2 per year (Ren et. al., 2007). About 0.4 billion people, 15 million hectares of cropland and 0.1 billion hectares of grassland have been negatively affected by desertification in recent years (ibid.). Desert ecosystems can be divided into five main types; small tree, shrub, sub-shrub and high and cold deserts.

Biodiversity and genetic resources

China is one of the world's mega-biodiverse countries, and possesses 83,000 species, accounting for 7.5% of the world's total (Tang et al., 2006). Among them, 30,000 species are higher plants, accounting for 10.5% of the world higher plants. The mountainous region of Southwest China is a biodiversity hotspot, with over 12,000 vascular plant species, approximately 30% of which are endemic. Vertebrate species richness is also high, including 92 species of freshwater fish, 92 reptiles, 611 birds, 90 amphibians, and 237 mammals. The Qinba mountains harbour over 6,000 species, and

have been referred to as a 'biological gene pool' (Guo et al., 2002), and the Changbai mountain region holds over 800 medicinal plants (Yang and Xu, 2003). There are more than 1,000 economic tree species found in China, and the country is the original and distributional centre of many wild and cultivated fruit tree species (Zuomin, 2003). China also has more than 11,000 medicinal plant species and the widest variety of domestic animals in the world. In Yunnan and the Qinghai-Xizang Plateau, areas of particular genetic diversity, 15-20% of species are threatened (MAWEC, 2005). The wetlands of China are particularly important sites for migratory bird species (An et al., 2007).

Ecological Zones

Many studies have been done to regionalize the territory of China into a hierarchical system of ecological zones, regions and sub-regions. Figure A2.2 shows the scheme of Ren and Bao (1988), which has 8 zones with 31 regions. IGCAS (1999) classified China into zones on the basis of climate factors for the first level zones, hydrological factors for the regions within the zones, and topological factors for the sub-regions (See Annex 5). On the basis of available regionalization schemes and recommendations of MAWEC (2005), this study has classified China into eight ecological zones, incorporating five zones recommended by MAWEC (2005) for western China for planning 'ecological construction'. The classification considers ecosystem services, fragility and similarity of environmental characteristics, and poverty distribution. Table A2.2 presents a preliminary analysis of these ecological zones in terms of the risk of poverty occurring due to their intrinsic ecosystem properties (see Annex 3 for definitions of terms).

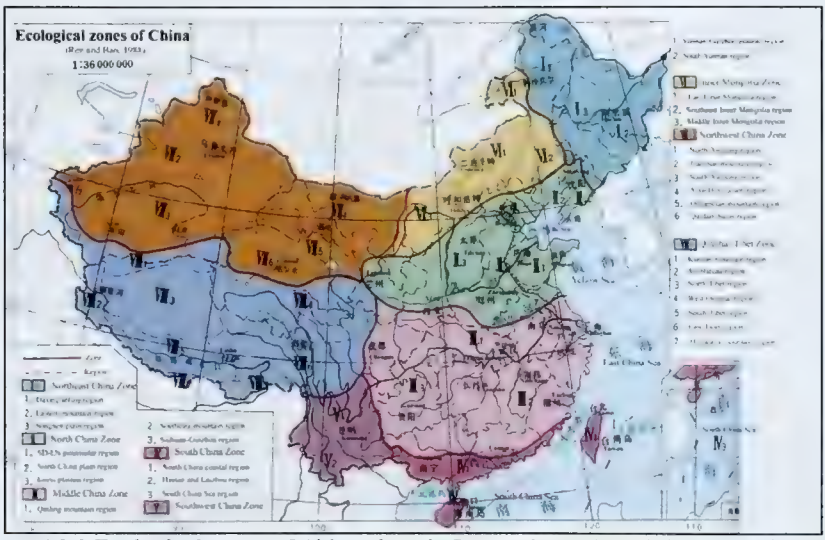


Figure A2.2 Ecological zones of China given in Ren and Bao (1988) (Source: Liu, 1998)

Table A2.2 Ecological zones of China and poverty risk due to intrinsic ecosystem properties.

Ecological Zone	*Ecosystem productivity*	*Ecosystem rest response*	*Ecosystem transformation risk*	*Poverty risk & requirement for special ecosystem management skills*
Loess Plateau	Low	Simplifying	Very high	Very high
Grassland in North China	Low	Simplifying	High	High
Arid region in northwest China	Very low	Simplifying	Very High	Very high
Karst region in Southwest China	Low-medium	Diversifying	Medium	Medium
Qinghai-Tibet Plateau	Very low	Simplifying	High	Very high
Plains in North China	High	Diversifying	Medium	Low
Plains in Northeast China	High	Diversifying	Medium	Low - medium
Mountains in Southeast China	High	Diversifying	Low	Low

Loess Plateau

The Loess plateau is mainly distributed in north Shaanxi, west Shanxi, east Gansu, Ningxia and south

Inner Mongolia, with an approximate area of 400,000 km^2. The landscape of the Loess plateau is characterized by deep valleys cutting through the thick layers of loess formed as result of wind-transported dust deposition. Due to scarce vegetation cover, low precipitation and very high risk of ecosystem transformation and a simplifying rest response of the ecosystem, the plateau is ecologically very fragile, and characterized by soil erosion (Figure A2.3). Low agricultural productivity together with poor infrastructure and education makes the plateau a major poverty region in China.

Grassland in North China

There is approximately 600,000 km^2 of grassland in North China, mainly in Inner Mongolia. The grassland zone has a high risk of ecosystem transformation to a degraded state, and is characterized by low precipitation and a shortage of water resources. Major grassland zones are located in the arid and semi-arid zones in western China, including Inner Mongolia Plateau, Qinghai Plateau, Shaanxi, Gansu and Xinjiang. Over 33% of grassland has been severely deteriorated because of long-term mismanagement of grazing and improper utilization (MAWEC, 2005). Agriculture and pasture husbandry are the dominant economic activities, with a major ecological problem of soil erosion by wind, which leads to reduced agricultural and livestock production capabilities, and a source of sand storms.

Figure A2.3 Agricultural landscape in Loess Plateau of China (Source: http://www.hoodong.com).

Arid region in Northwest China

This ecological zone is distributed in Xinjiang, western Gansu, western Qinghai and western Inner Mongolia, with an area of approximately 2.16 million km^2. Management of the area is important for combating desertification and sandstorms in the country. The area lacks water resources. Sandstorms occur frequently and some oases are already deteriorated. Hexi corridor in Gansu Province is one of the severest desertification areas in China. The Qilian mountainous region (located between Gansu and Qinghai provinces) is a major ecological conservation area for natural grasslands, forests and sources of rivers.

Karst region in Southwest China

This ecological zone mainly includes Guizhou, Guangxi and eastern Yunnan in southwest China, with an area of approximately 370,000 km^2. Its main characteristics are mountainous limestone areas with shallow soils, severe water-soil erosion risk and frequent drought and flood disasters. This ecological region is well-known for its unique landscape beauty and local nationality customs and folk architecture.

Qinghai-Tibet Plateau

This ecological zone is climatically cold and arid, of low productivity, the ecosystem is easily transformed into a degraded state, and responds to global climate change very quickly. The total area of Qinghai-Tibet Plateau is about 2.5 million km^2, accounting for above one quarter of China's extent. In recent decades major human induced exploitations in this zone includes overgrazing, timber extraction, mining and herb digging. These have caused decreasing forest area, grasslands

deterioration, desertification, rapid decreasing of wildlife resources and severe environmental pollution in parts of the plateau. Qaidam basin is arid and short of water resources, and also threatened by severe sandstorms. The Yangtze and Yellow Rivers both originate from this region and are strategically very important to the environmental and economic safety of the country. The region has been characterized by its landscape beauty with unique cultural tradition, world famous religious temples, lakes and grasslands. Zhuoni County, located in the south of Gansu Province, is a minority area and a national poverty county. It is one of the most important natural forestry reserves with many cultural remnants, including Qijia culture, Siwa culture and Majiayao culture, Tibetan empire tombs and other debris of Tang dynasty or Ming dynasty. Development of the tourism industry is viewed as a means to alleviate poverty in this zone.

Plains in North China

This ecological zone mainly consists of Beijing, Hubei, Henan, Shandong, Jiangsu and Zhejiang provinces, with an area of approximately 600,000 km^2. This zone is a major crop producing area, accounting for 57.25% of the modeled total crop production capabilities of China. Shangcai County, a national poverty county located in southeast Henan is one of the national production bases of high quality wheat. In 2005, the wheat industry accounted for 30% of the total GDP in the area.

Plains in Northeast China

This ecological zone includes Liaoning, Jilin and Helongjiang provinces with three plains in Northeast China: Liaohe Plain, Songnen Plain and Sanjiang Plain. Total territory is approximately 790,000 km^2. Soil organic content is the highest in China, making these plains important agricultural regions, featuring maize and soybean farming. In spite of fertile soil and rich rainfall, low temperatures are a major constraint for agricultural production. Poverty counties in this zone are mainly located in the north, where the growing season is short. In recent decades conversion of wetland into cropland has led to a dramatic change of land cover.

Mountains in Southeast China

This zone mainly includes Fujian, Zhejiang, Jiangxi, east Hunan and south Anhui, with an area of 700,000 km^2. Compared with western and central regions, Southeast China is an economically developed region. However, areas of poverty are found in the mountainous areas, even in coastal regions. Soil and nutrient erosion is very serious, with low agricultural production and economic development.

Box—Key Messages

The potential for poverty reduction through ecosystem management varies greatly across China due to the intrinsic properties of different ecosystems and zones. Table A2.2 presents a first assessment by this study of each ecological zone in terms of the risk of poverty occurring due to intrinsic ecosystem properties (see Annex 3 for definitions of terms). This analysis found that the risk of poverty is very high in the Loess Plateau, Qinghia-Tibetan Plateau, and the arid region in northwest China, and high in the grassland zone of northern China. It is significant that these high poverty risk regions are predominantly grasslands with seasonal rainfall, and their sustainable management requires an understanding of the ecosystem processes of each grassland type and the livelihood practices which have developed with them. These grasslands co-evolved with abundant populations of antelope and other herbivores, whose populations and local distribution were greatly influenced by predators such as wolves. The nomadic lifestyles of many of the indigenous peoples of these regions, centred on livestock management, have also evolved to respond to the high year-to-year variability of rainfall that largely determines local ecosystem productivity. The increasing desertification of grasslands in modern times, and the high levels of rodent plagues and insect pests, indicate that major disruptions of ecosystem processes have become widespread. Lintai (2005) reported that fencing of Inner Mongolian grassland and the change from nomadic to settled lifestyles of herders can result in grassland degradation. Other types of grassland will respond differently to these management practices, and ESPA-relevant research needs to have greater consideration of different ecosystem properties for grasslands and all types of ecosystems.

A3 – Supply of Ecosystem Services in China

The link between the environment and poverty in China has been established in previous sections, and areas of ecological vulnerability identified. This section aims to build upon this with a summary and assessment of the state of knowledge of the supply of major ecosystem services in China at a national and sub-national regional level. Since many ecosystem services are not analysed systematically, the knowledge constraint is a major gap in the assessment of supply of ecosystem services in China. One of the principle information sources is the Integrated Ecosystem Assessment of Western China (MAWEC), which was a sub-global assessment within the Millennium Ecosystem Assessment (MA). A summary of knowledge gaps and the volume of literature for China for each ecosystem service are presented in Annex 6.

Provisioning services

Provisioning ecosystem services are the physical goods and products which people obtain from ecosystems, such as food, timber, fuel and freshwater.

Forest Ecosystems

Timber

Whilst China's forest timber volume stands fifth in the world at 124.56 billion m^3, this equates to a per capita forest timber volume of only 9.421 m^3; less than one sixth of the world average (Ren et al, 2007; Li, 2004). 78% of the timber stock is made up of young and middle age forests, and consequently the available timber is mostly of low quality (Albers et al. 1998). China's demand for timber by 2010 is projected to be 320 million m^3, exceeding projected supply by 70 million m^3 (Zheng et al, 2001). The plantation forestry area of China has a timber volume of 15.05 billion m^3 (Ren et al., 2007). It has been estimated that plantations will provide 150 million m^3 of wood annually (Jiang & Zhang, 2003), mostly in eastern and middle China.

Bamboo

China is the richest country in the world in terms of bamboo resources; 7.2 million ha of bamboo-based forests comprise approximately 10% of the country's tropical and subtropical forests. The standing biomass is estimated at more than 96 million tons (MA, 2005), and bamboo consumption is increasing, including as a high quality substitute for timber. Over 4.2 million ha of natural bamboo forests have been turned into monoculture forests (Jiang, 2003).

Non-Timber Forest Products

Non-Timber Forest Products (NTFPs) such as fruits, mushrooms, bamboo, rattan, ornamental plants, medicinal plants, honey, and bush meat have become an increasingly important resource in China. Following the restrictions placed on the declining timber resources NTFPs in many regions are more important to the economy than timber (Yang et al., 2006a). China is a major exporter of NTFPs, and they are also an important source of food and cash income to rural households, but few inventories of the status and supply exist nationwide. Honeybees have a key role in ecosystem functioning and provide a vital regulating ecosystem service as pollinators of 1,100 crops and plants in natural ecosystems. China has 7 million bee colonies, and is the largest producer of honey and royal jelly in the world, representing 300 thousand and 3,000 tones each year, respectively (Chen et al., 2005).

Fuel wood

Fuel wood is estimated to provide 40% of the fuel for rural households (Harkness, 1998), and is the main source of energy in rural China, but demand far exceeds supply in western China (MAWEC, 2005).

Wetland ecosystems

Fresh water

China's annual per capita water availability is approximately 2,300 m^3, a quarter of the world average (Chinese Statistical Yearbook, 2006). China's total quantity of water resources in 2006 were 2,556.7 billion m^3. It is estimated that 200 million people in China currently have no easy access to clean drinking water (Reid et al., 2007) and that 47% of the population is water stressed (with annual per capita water availability of less than 750 m^3). The surface and ground water resources of north China are excessively exploited, with utilization up to 66% and 90% percent respectively (Stern, 2006). In some areas of China, such as the Xinjiang and Qilian areas, glacial water melt accounts for 22% of the direct inland water supply (Liu et al., 2005), and 250 million people are dependent upon this service

(Stern, 2006).

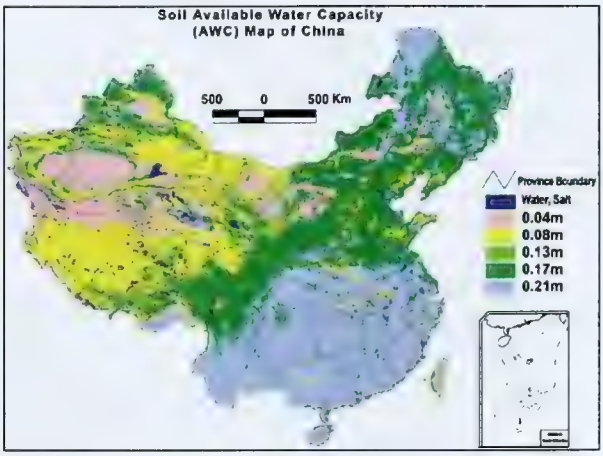


Figure A3.1 The available water capacity of soil in China (Feng et al, 2007)

China uses more than 75% of its fresh water supplies for agriculture (MA, 2005), and water shortages in the northeast are exacerbated by shifts from dry field to paddy field, which consume much more water and lower groundwater tables further (Liu and Diamond, 2005). However, China's water resources for agriculture are also characterized by low availability per capita, with uneven regional and seasonal distribution (Chen, 1992), as highlighted by the available water capacity of soil (Figure A3.1). Agricultural production is estimated to be reduced by 35 million tons per year due to lack of water (Zhang, 2007b).

Fisheries and Aquaculture

China is the largest global producer of aquaculture products and production in 2005 totalled 2.26 billion tonnes (Chinese Statistical Yearbook, 2006). Between 1970 and 2000, inland water aquaculture production increased at an average annual rate of 11% (FAO, 2004, in MAWEC, 2005), and demand increased ten fold (MA, 2005). It is estimated that 2 million tons of fish and other aquatic animals are consumed in the Mekong basin, of which 1.5 million tons are from natural wetlands (Sverdrup-Jensen, 2002)

The Yangtze River is the most developed freshwater fishery in China (Chen et al, 2004), with 60% of the total freshwater species catch. (MA, 2005). Although fish production has been proven to be a vital source of income for poor households across Asia, there no published information of the importance of fish to the poor in China was found.

Livestock and farm products

Livestock

The total meat provisioning capacity of western China's grasslands accounts for 68.57% of the total in China, with a theoretical production capability of 5,700 billion tons hay per year, equivalent to 4,490 billion standard sheep units of livestock (MAWEC, 2005). The pork production sector produces 70% of all meat in China, and 50% of the world production (MA, 2005). The south, southwest and east of China produces 80% of the total pig output.

Food crops

China's agricultural production has grown substantially over the last 30 years and grain output is expected to reach 501.5 million tons, which is 95.1% of the expected total consumption of 527.5 million tons.

The average cropland area per capita is 0.1 ha, which is 40% of the world average (Zhou, 2002). There has been an increase in the extent of cultivated land between 1986 and 2000 of 2.7 million ha across China as a whole (Deng et al., 2006). However, the bio productivity of the area fell over the same time frame, with a 5855 billion kcal (0.3%) decrease in total production potential. Provinces in north China such as Beijing and Tianjin largely accounted for the fall in productivity.

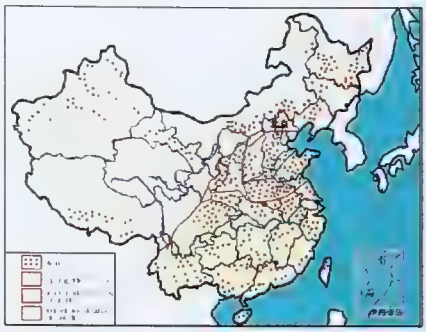


Figure A3.2 The distribution of wheat production in China (Source: Institute of Agricultural Resources and Regional Planning, CAAS; drawn according to The theory and practise of agricultural regionalization of China, 1993)

Western China, has a lower gross and per area unit output of grain in comparison to China as a whole, accounting for only 27% of the grain output (MAWEC, 2005). The southwestern region has favourable climatic conditions and sufficient water resources for farmlands, resulting in much higher yield of grains than that of northwestern China. The modelled food provisioning capability of the major terrestrial ecosystems in western China is shown in Figure A3.3.

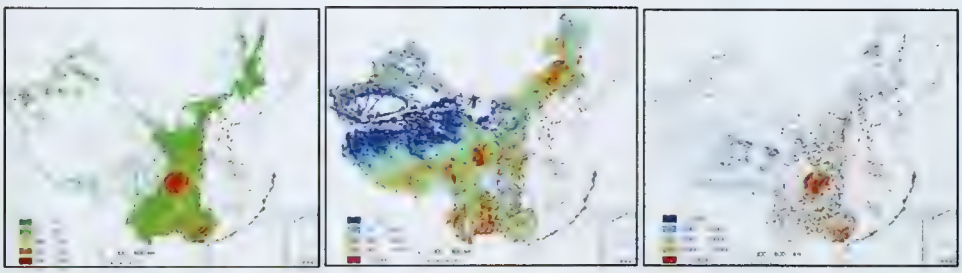


Figure A3.3 Modelled ecosystem food provisioning services in the western region of China and the distribution of poverty counties (left map: farmland ecosystem (t/km^2); middle map: grassland ecosystem (kg mutton/km^2); right map: water ecosystem (kg fish/km^2)) (Source: MAWEC, 2005)

Fibre crops

China's share in global production in the year 2000 was approximately 23.7% (MA, 2005), and the yield of over one ton per hectare was significantly higher than the global average. In China, an estimated 50 million families grow cotton, and cotton therefore competes with food crops for available land, water, time, and energy (MA, 2005). Xinjiang province in western China is a major cotton supplier (MAWEC, 2005).

Regulating services

Regulating ecosystem services are the benefits people obtain from the regulation of ecosystem processes, including, for example, the regulation of climate, water flows and purification, and the occurrence of some human diseases.

Historical land use policies have often managed the major ecosystems of China without consideration for their regulating ecosystem services. However, this has now changed dramatically, especially following devastating floods in the Yangtze River area in 1998, with policies and programmes such the National Forest Protection Programme (NFPP) and the Sloping Lands Conversion Programme (see Section B2).

Erosion regulation

Soil erosion is a major problem in China, with annual soil loss of approximately 5 billion tons, half of which was contributed by the Yangtze area. In addition, approximately 1.6 billion t/a of mud and sand are eroded into the Yellow River. This impacts upon the provisioning services of the river ecosystem

in terms of fish, food, and fresh water. Farming on steep slopes has been cited as a major cause of soil erosion (Wang et al, 2005).

It has been estimated that forests in areas involved in the NFPP will reduce soil erosion by 1.505 billion tonnes, containing 1.5 billion kg of nitrogen, 1.05 billion kg of phosphorus and 6.02 billion kg of potassium per year (Zheng et al, 2001). Similarly, the Yaoluoping National Nature Reserve, a watershed for the Yangtze and Huaihe rivers, has reportedly reduced soil erosion by 1.44 million t/a (Xu et al, 2003). Soil erosion reduction by forests in Xingshan county has also been estimated to be high, with 42.2 million tonnes of soil and 16.6 million m^3 silt, including the prevention of 6.83 million m^3 soil entering the water system each year (Guo et al, 2001).

There is a noticeable lack of information on the contribution of grassland to erosion regulation. However, the headwaters of economically important Chinese rivers such as the Yangtze and Yellow Rivers are located in grassland areas (Zhang et al, 2007), and the degradation of this land is recognised as a major cause of soil erosion. It has been estimated that for every 0.06ha of grassland converted to cropland, 0.47 ha of land becomes desert (Wang et al, 2005).

Water regulation

The ecosystems of China are vulnerable to flooding, largely due to monsoon weather patterns and land use practices. On average, floods affect more than 100 million people annually (MA, 2005). Equally, seasonal patterns of rainfall make water regulation by natural ecosystems a vital part of the economy in terms of dry season water availability, particularly in the northern areas. A study of a watershed in Xingshan County, Hubei province (Guo et al 2001), estimated that the watershed retains 868 million m^3 of water in the wet season, thereby decreasing the flow of water in the Yangtze and reducing incidences and magnitude of flooding. In the dry season, the watershed discharges approximately 80 million m^3 of water, increasing the water flow in the river. This study emphasized that the spatial distribution rather than extent of forest was a determining factor in water regulation; an issue that has largely been ignored (Guo et al, 2002).

Wetlands are recognised as providing valuable flooding prevention services. However, whilst recognition of this has slowed conversion of wetlands to crop and urban land in some areas, there has been little examination of their ability to prevent flooding. Wetland soils in the Momoge Reserve, Jilin province, have an estimated flood mitigation capacity of 7.15×10^4 m^3/ha/yr, translating into an estimated economic benefit of US$5700/ha/yr (Ming et al, 2007). Whilst it is also recognised that grassland plays an important role in water regulation in China (Zhang et al, 2007) little information exists on this topic.

Water conservation by ecosystems is extremely important in northern areas. Guo et al (2001) calculated that water conservation by forests in Xingshan county (Hubei province), taking into account rainwater intercepted by the canopy, held in litter and contained in soil, was approximately 25 million m^3/yr. Modelling suggested that the forest ecosystems throughout the entire region contributed 42% of the water conservation in the area. It has also been estimated that natural forests involved in the NFPP can contain 25 billion tonnes of water (Zheng et al, 2001). The estimated increase in water resources by forests in Heilongjian Province was 23 billion m^3, or 36% of the water resources of the province (Cai et al, 1996).

Most published studies have concentrated on the value of forest ecosystems for water conservation. However, the main water deprived region mainly consist of grassland and 82% of all freshwater resources are contained in wetlands (An *et al*, 2007), but their role in water conservation remains unquantified.

It has been estimated that wetlands remove 4.6 Tg of total nitrogen, and 0.6 Tg of total phosphorous from water resources in China (An et al, 2007). However, the continuing loss of wetland area across China has potentially led to a reduction in annual water purification by 2.8 Tg nitrogen and 0.4 Tg phosphorous, amounting to 151% and 64 % respectively of the total nitrogen and phosphorous discharged in 2000 (not including agricultural discharges).

Climate regulation

Ecosystems influence the global climate through sequestration or liberation of the greenhouse gas (GHG) CO_2, which is held as carbon in the soil and vegetation. There are a number of varying estimates of the soil organic carbon (SOC) stocks in China, likely due to the use of different datasets (Xie et al, 2007), and the proven effects of scale in soil carbon mapping (Zhao et al, 2006). Such estimates range from 50 to 185 Pg (Xie et al, 2007), and data must be treated with caution due to limited data and inconsistent methodologies. However, a recent study of SOC in China, taking into account varying ecosystem types and regional discrepancies (Xie et al, 2007), estimated an SOC value of 98.77 Pg over 960Mha, similar to that of 92.42 Pg estimated by Wang (2001), and 89.1 Pg estimated by Yu et al (2007). SOC pools were largest in the northwestern and southwestern regions (fig A3.4; Xie et al, 2007; Yu et al, 2007).

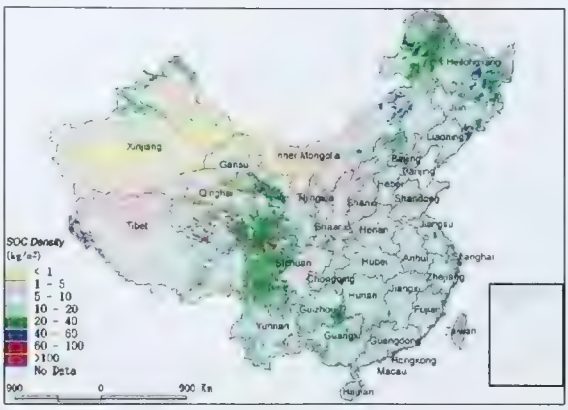


Figure A3.4 Map of soil organic carbon density in China (taken from Yu et al, 2007)

Forest and grassland soils have been estimated to have the highest SOC stocks of 34.23 and 37.71 Pg respectively (Xie et al, 2007). However, a much lower SOC stock was estimated for grasslands by Yu et al (2007); possibly because desertified grassland was included in grassland estimates, whereas shrubland was not. Similarly, there are 13,000 km^2 of peatlands in China, the majority of which are distributed on the Qinghai-Tibet Plateau (QTP), with a carbon (C) storage capacity of 0.35 Eg (10^{18}g), and as some studies do not include these in their grassland estimates, comparison is difficult. Wetlands have been recorded to have the highest mean SOC in China with 109.9 t C/ha, and desert ecosystems the lowest at 29 t C/ha (Yu et al, 2007). Although wetlands have been shown to have good carbon sequestration capabilities globally, there is a notable lack of data from China on this topic (Zedler and Kercher, 2005).

Vegetation carbon storage is estimated to be lower than that of soil; studies on the grassland vegetation carbon storage have estimated a total of 3.32 Pg C in China, with 56% concentrated on the QTP, and 18% in northern temperate grasslands (Fan et al, 2008). On a more localised scale, it has been estimated forests in Xingshan county fix 166,413 tonnes of CO_2 per year, supplying 122, 513 tonnes of O_2 (Guo et al, 2001), whilst carbon stored by forests in the Changbaishan mountain biosphere reserve (CMBR) has been estimated at 4.3 million t/a (Xue and Tisdell, 2001). NFPP forests can absorb an estimated 31.263 tonnes SO_2, 15.88 million tonnes NO_2 and 91.95 tonnes CO (Zheng et al, 2001), and the mean carbon storage in the biomass of poplar plantations has been estimated at 3.75×10^7 t ha^{-1} yr^{-1} (Fang and Tang, 2007)

Trends over the past 20 years suggest that forested land acts as a major carbon sink in China (Xie et al, 2007). Studies taking into account above ground biomass in addition to SOC have identified similar trends (Wang et al, 2007; Ni, 2004; Pan et al, 2004), and this is also in agreement with studies of forested areas, estimating forest carbon storage to be 0.021 Pg/yr (Fang et al, 2001) and 0.019 Pg/yr (Piao et al, 2005), with the most carbon sequestration taking place in the northeast and southwest (Wang et al, 2007). This trend is likely to continue over the next decade as plantations mature (Zhao and Zhou, 2005). However, degradation of grassland, particularly on the QTP, has transformed the grassland soils into a net carbon source, emitting 3.56 Pg SOC. Similarly, some studies have calculated that croplands act as a carbon source (Li et al, 2003). It is therefore estimated that the soils

of China act as a net carbon source, with a loss of 2.86 Pg (Xie et al, 2007). Large regional discrepancies exist, however, with eastern and southern China acting as a carbon sink, whilst northwest China is a major source; the northeast and southwest to a lesser extent. The highest SOC losses were experienced on the QTP.

Disease and pest regulation

There is little available information on the role of ecosystems in regulating disease in China. However, water run-off that ensures fast flowing rivers has been suggested to be a factor in the regulation of schistomisoasis, and there are concerns that the increase of dams in China to control flooding will cause an increase in the incidence of this parasite (Chen et al, 2004). Research has suggested that the number of malaria cases is significantly reduced if rice paddies are stocked with edible fish and nitrate levels kept low. Rice paddies are also a breeding ground for Japanese encephalitis (MA, 2005). Similarly, there is little available information on the role of ecosystems in regulating pests in China. However, it has been suggested that changes in forest composition have been partly responsible for insect infestations that have caused the loss of more than 10 million m^3 timber (Li, 2004).

Supporting services

Supporting ecosystem services are those that are necessary for the production of all other types of ecosystem services, and include photosynthesis, nutrient cycling and soil formation. They can also be called ecosystem processes. Whilst their functioning largely determines the status of all other ecosystem servicesthey have received very little attention relative to their fundamental importance to China and the Chinese economy.

NPP & NEP

The total Net Primary Production (NPP) of China's landmass has been estimated to be 2.235 Gt C (Feng et al, 2007). NPP in China is unevenly distributed (fig A3.5(a)), and is particularly low in western China (Li, 2004), with the exception of the southwestern provinces of Tibet, Sichuan, and Yunnan (Feng et al, 2007). An in-depth study of the QTP highlighted a similar local scale pattern of a decrease in NPP from the southeast to the northwest (Luo et al, 2002). Forested areas had the highest NPP at 922×10^6 t C, followed by cropland at 624×10^6 t C. Grassland had a lower NPP at 357×10^6 t C, whilst the NPP of barren land was estimated at only 26×10^6 t C (Feng et al, 2007). Although various studies give different estimates of NPP in China, likely due to varying methodologies and uncertainty in modeling NPP, the general patterns of distribution remain the same.

(a) **(b)**

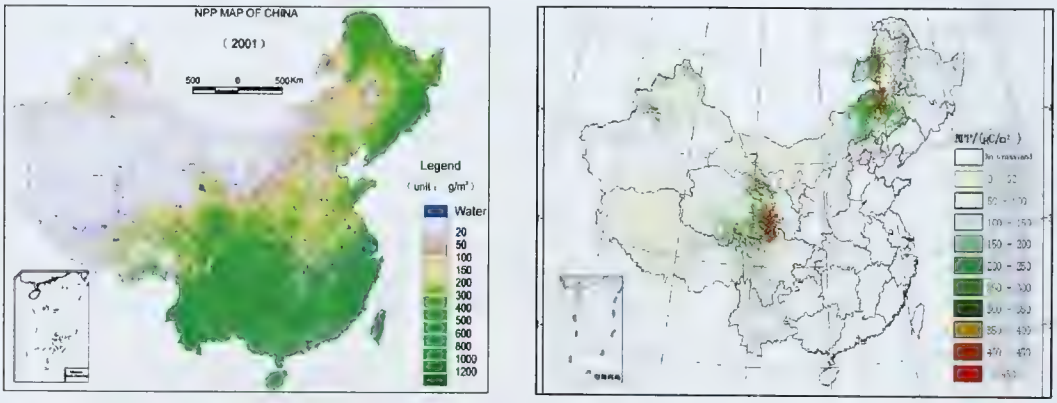
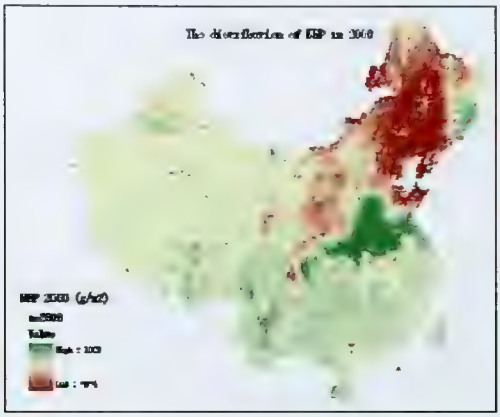


Figure A3.5 (a)Distribution of NPP in terrestrial ecosystems of China (Feng et al, 2007); (b)The distribution of annual NPP of Chinese grassland in 2005 (Source: Jiang Lipeng, Valuating Ecological Functions of Chinese Grassland using Remote Sensing Technology[D]. 2007)

The distribution and annual NPP of grassland in China can be seen in Figure A3.5(b). From the remote sensing data, it is obvious that the NPP is highest in eastern Qinghai, western Sichuan, northeast of Tibet, southeast of Gansu, northeast of Inner Mongolia, and the western part of Xinjiang. The rest of

the country has medium to low NPP, and this can be contextualised in relation to the issue of land degradation, which has severely reduced the NPP of this area and therefore the servicing capabilities of grassland ecosystems.

Figure A3.6 shows the estimated distribution of Net Ecosystem Production (NEP) in China. The distribution of NEP is quite variable, and the highest level of NEP is centred in the central, south and southwestern part of China. In northwestern China and some coastal area, the level of NEP is medium. But, in the north and northeast China, the distribution of NEP is fairly low.



FigureA3.6 The distribution of NEP in 2000 (Source: Data Centre for Resources and Environmental Sciences Chinese Academy of Sciences (RESDC))

Nutrient cycling and soil formation

There is little available information on the nutrient cycling and soil formation services of terrestrial ecosystems in China. However, it has been widely acknowledged that the quality of soil has been reduced as a result of destructive land use practices, degradation of land, and the use of fertilizer on cropland ecosystems. This is particularly the case in grassland ecosystems, which are suffering from desertification at an increasing rate. The value of nutrient cycling for the terrestrial ecosystems of China was estimated to be RMB 324 billion yuan per year in 1995, whilst that of organic matter production has been estimated at RMB 23.3 trillion yuan. The increasing rate per year and tendence of soil organic carbon can be seen below (Fig A3.7). It showed nicely the loss of soil organic carbon from grassland areas and increase in the cropland areas.

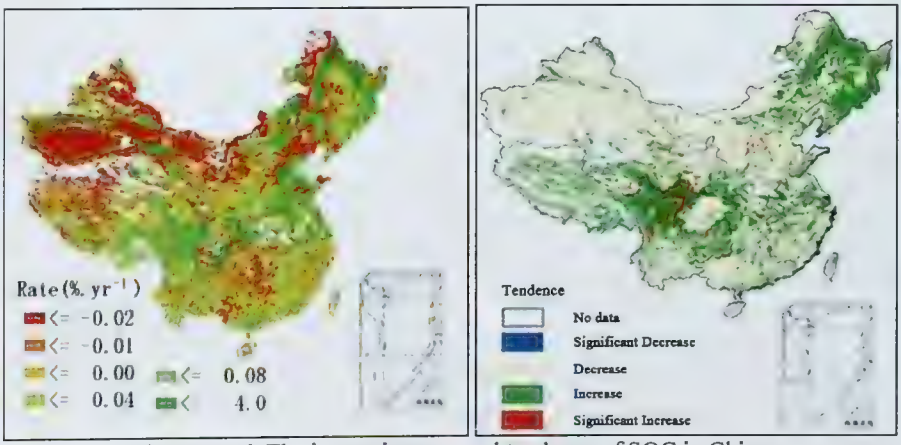


Figure A3.7 The increasing rate and tendence of SOC in China

Cultural services

Cultural ecosystem services are the non-material benefits that people obtain from ecosystems, such as recreational, educational, aesthetic and spiritual benefits. Although China is extremely culturally

diverse, there is very little available information on cultural ecosystem services in terms of spiritual and religious values, knowledge systems, educational and aesthetic values, social relations, cultural heritage values, and recreation and tourism. These values are often overlooked (MA, 2005).

Spiritual and religious values, cultural heritage

Indigenous people in China have long traditions of product cultivation; the Hani grow rattan and tea, the Miao cultivate Chinese fig, and the Yao, Hani and Jinou people cultivate medicines in the Yunnan province. China also has many sacred groves (Xu & Melick, 2007), although no information is available on the amount and distribution of such cultural areas. Yunnan province in particular, with 26 different ethnic groups (Pei, 2005), has been identified as a centre of cultural diversity, harbouring many important cultural sites such as sacred forests, temples, and sacred mountains (Luo et al, 2005). In Tibet, a wide range of sacred sites have been maintained for centuries, and are crucial for maintenance of the Tibetan cultural system. Human activity in these areas is strictly controlled. The Menri or 'Medicine Mountains' in southeastern Tibet is an important cultural site, as is Mount Kawa Kapo, the highest mountain in Yunnan; one of the most sacred mountains in Tibetan Buddhism. This area is believed to be the home of a number of deities, and is surrounded by over one hundred sacred sites (Xu et al, 2006).

Southwest China hosts six of the thirty UNESCO heritage sites of China, in which cultural and biological diversity are closely linked (Xu et al, 2006). These include the Jiuzhaigou Valley area, the Donga culture in Lijiang, ancient irrigation systems, and the three parallel rivers of Yunnan. The Naxi people worship the spirit of nature, Shu, and in the Dai tradition gods reside in the holy hills (Pei, 2005). Xishuangbanna is a Dai area, and has 558 Buddhist temples, numerous sacred groves that normally exist near the temple areas, and approximately 250 holy hills that occupy 1000-1500 ha of land (Hu, 2005). All plants and animals within these hills are believed to be sacred. Yunnan is home to approximately 1.25 million Hani people, who believe that mountain forests have their own spirits, and any human activities in these areas are taboo. Grasslands are also considered to be a spiritual landscape by nomadic Tibetans. The mountain gods are believed to govern the people and nature, and there are over fifteen sacred mountains in the Tibetan region (Xu et al, 2006).

Tourism resources are a major feature of the Qinghai-Tibet Plateau. Lhasa and adjacent areas have many world-famous religious temples, plateau lakes, plateau grassland, and pastoral camps. On the north side of the Himalayas, the tourist region consists of five mountains higher than 8,000 m and the Everest nature reserve. The "Tea, Horse and ancient roads" tourism starts in Shangrila of Yunnan province, passing through Changdu brine well, Ranwu Lake, Bomi, Brahmaputra Canyon to Lhasa. The development of ecotourism is an option for poverty alleviation in this area.

Box—Key Messages

It can be seen from the summary above that the majority of available information on ecosystem services in China is for the provisioning services that provide the largest immediate financial and material gain. However, various ecosystem service valuation studies have put the regulating and supporting services provided by ecosystems at a higher value than the provisioning services (Xu and Tisdell, 2001; Xu et al, 2003). The provisioning services of cropland areas should also be viewed in the context of the relative lack of regulating and supporting services that these ecosystems provide. Various attempts have been made to cost the impact of land degradation in China, with one estimate placing direct costs at $7.7 billion and indirect costs at $31 billion (Berry, 2003). Increased land degradation and lowered land productivity reduces the supply of ecosystem services, and without appropriate management, the cycle of poverty and environmental degradation is mutually reinforcing. If natural disasters are considered, the relationship between poverty and the environment becomes even stronger (Juanlin, 2001).

It is clear that many of the provisioning ecosystem services in China are either in decline, or increasing at a rate slower than demand. This may in large part be due to previous land use policies focusing on management for provisioning services with inadequate recognition of the importance of regulating and supporting ecosystem services.

A4 – Importance of ecosystem services to the poor in China

This study found little socio-economic data and studies that could provide detailed or systematic evidence of the linkages between ecosystem services and the poor in China. Available data on the population in poverty at the level of poverty counties is mostly too broad for specific analysis of different livelihood strategies and relationships with the natural environment. Also, as the concept of ecosystem services is still new this type of analysis often requires re-interpreting studies conducted for other purposes. However, this project's Ningxia region case study found that considerable data on poverty, livelihoods and ecosystem status does exist within the government system and can be analysed to identify key issues for ecosystem management and poverty reduction. This section of the report first summarises the importance of ecosystem services to the poor in China, then provides evidence or examples for these relationships.

Box—Key Messages

It is clear that food provisioning services are crucial for poor people in China, and the importance of water provisioning for food production and health is consistently reported. Information on the significance of forestry and fisheries provisioning services is less clear, but collection of NTFPs and artisanal fishing may be crucial in some areas. The role of fuel provisioning ecosystem services in rural livelihoods is rarely mentioned, although fuelwood demand exceeds supply in western China, especially in grassland regions. The most important regulating ecosystem services for the rural poor involve the hydrological cycle at different scales, from the supply of water for agriculture and health to influencing the magnitude of the floods and droughts that are major causes of poverty in China. Cultural ecosystem services can be of significant importance for tourism income around protected areas and sacred sites, as well as central to the values and cultures of many of China's ethnic groups.

Generally, there is a lack of information on the relative importance of different ecosystem services to the poor; in particular for the consideration of trade-offs between the supplies of provisioning and regulating services and the ecosystem processes that support them.

Importance of agricultural provisioning services

- Zheng et al (2001) have estimated that 95% of the rural poor rely on farming activities, and that 75% of these people live in ecologically vulnerable areas.
- In grain producing areas 15.4 million people were living in poverty in 2002, constituting 55% of the total rural poor (Yanlin, 2004). It is estimated that 20 million people in western China live in poverty due to a lack of water and suitable agricultural land (Yanlin, 2004).
- A project aimed at improving agricultural yields in the Yellow and Hai River plains reportedly lifted 30 million rural inhabitants out of poverty (Zheng et al, 2001).
- An indication of the importance of agricultural provisioning services to the poor is provided by data on government payments in state-designated poverty-stricken counties. RSDCBS (2006) report that 52% of payments are for crop plantation and 38% for animal husbandry. Forestry and fishing make up less than 2% of payments and the contribution of secondary and tertiary industries is small (8.7%), which highlights the importance of natural resources in rural incomes. The same report found that 68% of livelihood expenditure in poverty counties goes on food.

Importance of forest provisioning services

- Sixty percent of China's forests are owned by local communities and play a critical role in maintaining livelihoods through timber and NTFP provision, including bamboo (Zhao and Xu, 2004; Miao and West, 2004). However, even in Yunnan province, which has a relative abundance of forest resources, 57% of its counties are below the poverty line (Weyerhauser et al, 2006).
- A project involving afforestation with commercial trees and forest improvement in Huoshan county, Anhui province, led to an increase in annual household income of 180% in demonstration households, and 113% in surrounding households (Zhao and Xu, 2004; Li and Zhao, 2004).

- In 1995 fuel wood accounted for 15% of the energy supply for China's rural population (SEI and UNDP, 2002).

- NTFPs are important resources for the poor in China and in some regions they are the primary source of income (Miao and West, 2004). A project promoting the sale of forest mushrooms in Taiyang township resulted in an average net income of RMB 427 yuan per person (Zhao and Xu, 2004; Xu et al, 2005). Over 550 species of medicinal plants and hundreds of food plants are traded by mountain people (Mishra, 2000; Miao and West, 2004). Harvest of the matsutake mushroom in the Tibetan area of Yunnan province had a value of $44 million in exports in 2005 (Yang et al, 2006b). This resource has been in decline, however, with production of 530 mt in 1954 reduced to 272 mt in 2005 (He and Weyerhauser, 2006).

Importance of water provisioning services

- The quality of water provisioning services is obviously linked to poverty. For example, in Tibet, which has the lowest HDI index in China, 80% of the population is exposed to unsafe drinking water (SEI and UNDP, 2002).

- The reliance upon irrigation for agriculture makes the problem of water shortages one of the main issues facing the poor in northern China (SEI and UNDP, 2002). Whilst irrigation increases crop yields and farm incomes, with revenue from irrigated plots exceeding those from non-irrigated plots by 93% in poor areas, it also increases the reliance of the poor on grain with a high water requirement (Huang et al, 2006; Mishra, 2000).

Importance of grassland provisioning services

- There are approximately 100 million people residing in grassland regions, of which 11 million are pastoral herders (SEI and UNDP, 2002). Poverty levels amongst grassland-dependent people are 41% in Xingjiang, 35% in Qinghai, and 18% in Inner Mongolia, against a national average of 11%.

- In Inner Mongolia, 25 million heads of livestock are the backbone of the economy and provide livelihoods for 192,000 herding families. These pastoral areas were once the major livestock producers in China, but have seen a large decrease in their share of total production (Ke, 1998), and it is now estimated that the low carrying capacity of the grasslands (2 hectares are required to feed a single sheep) can support the livelihoods of fewer than 5 million pastoral herdsmen (Jun, 2006).

Importance of regulating services to the poor

- Ecosystems can reduce or regulate the impact of extreme weather events on poor people, which is of major importance in China because natural disasters are now the main cause of people falling back into poverty (Bass and Steele, 2006; ADB, 2003).

- The huge Yangtze River flood in 1998, for which deforestation and land degradation in the watershed were contributory factors, displaced 223 million people and destroyed 25 million hectares of cropland (UNDP, 2003). China experienced an average of 5.8 floods per year from 1950-1990.

- Severe drought in 2002 resulted in the loss of 6.43 million hectares of crops.

- In northern China, snowstorms resulted in the loss of 400,000 livestock in Inner Mongolia at a value of RMB 350 million yuan, and 100,000 livestock in Xinjiang at a loss of RMB 230 million yuan (UNDP, 2003).

- Guanxi province has experienced an estimated 5-10% loss of food crops as a result of acid rain (SEI and UNDP, 2002).

- Sandstorms have been increasing in frequency and appear to be a direct consequence of grassland degradation (Liu et al, 2004).

- The water purification services of ecosystems are vital to poor people in areas in which sanitation is poorly developed. Roughly 200 million people live in small towns without sanitation (SEI and UNDP, 2002), and rely on the steadily reducing runoff of clean mountain water.

- One million tons of grain production is lost due to unfit water and salinisation. Groundwater is also often polluted, with limited water treatment available to the rural poor. It is estimated that salinisation of land reduced national yields by 2% during the reform period, and studies have

suggested that without land degradation rice would have grown 12% faster, the figure rising to 20% for grain and maize crops in north China during 1980 to 1990 (Rozelle et al, 1997).

- Restoring the floodplain in the Lake Dongting region has reportedly contributed to a 100% increase in the incomes of local farmers (Schuyt, 2006), through reduced flooding and lowered heavy metal index of the water, and a subsequent increase in productivity of the land.

Importance of supporting services to the poor

- Whilst agriculture is of vital importance to the rural poor the cost of degradation of soils and erosion in China has been valued at a loss of 4 to 6 times that of annual agricultural products (Berry, 2003).
- In grasslands land degradation has resulted in a 30-50% reduction in grassland biomass since 1950, which has resulted in the lowered livestock carrying capacity and an increase in dust storms (SEI and UNDP, 2002).

Importance of cultural services to the poor

- Cultural ecosystem services are likely to be of major importance to the quality of life of millions of rural poor in China, but few published studies were found on this topic. Domestic and international tourism in China is rapidly expanding and ecotourism involving local communities around nature reserves is being promoted. Li et al. (2006) report that residents left farming and hunting to be part of the tourism business around the Jiuzhaigou Biosphere Reserve.

Box-Ecosystem and Poverty Linkages in Ningxia

The Ningxia Hui Autonomous Region is located in northwest China in the middle reaches of the Yellow River and has an area of 66,400 km^2 and a total population of 6.04 million, of which 65,000 are below the absolute poverty line and 293,000 below the low income level. Eight of Ningxia's 22 counties are official poverty counties and the poverty-stricken people are mostly distributed in the desertified central district and loess hills. In 2006 around 39% of Ningxia territory suffered from water and soil erosion and 22.8% from desertification. Whilst the rural population increased by 4.6 times from 1949 to 2.45 million people in 1999, the per capita grain availability was largely maintained at about 310kg by an expansion of 50% of farming areas to mountain slopes. Cultivation on slopes was at the expense of forest and grass cover and caused erosion rates of 12,400 $t/km^2/yr$. Degradation of the grasslands by over-grazing resulted in vegetation coverage of soils of between 20 to 70% by 2000.

With annual precipitation varying from 200mm to 600mm according to local topography, water deficits are a major constraint on the functioning of the ecosystem processes and the supply of ecosystem services. The scarcity of water has close relationship with inactive soil microorganisms and low production of organic matter and very slow cycling of minerals and energy in the ecosystem, with a very simple ecosystem structure. Loss of vegetation cover and wind and water erosion further reduce the availability of minerals and the retention of any rainfall in the ecosystem to support plant growth or recharge groundwater. In 2004 severe drought resulted in most of the rivers in the poverty-stricken areas drying up and 2.2 million people suffered from drinking water shortage and a great or even total loss of crops. Drought has occurred in 41 of the last 57 years and is increasing in frequency and severity.

Worsening functions of the ecosystem, declining soil fertility and low and unstable grain production have worsened poverty. Off-farm income has been low and farmers have little capacity against natural disasters, which cause farmers to fall back into poverty.

(Source: Ningxia Commission of Development and Reform (2008) Strategic Studies on the Ecological System Beneficial Cycle and Poverty Reduction in Ningxia – Report for the China ESPA Project. 54 pp. See summary in Annex 4.)

Section B: Decision-making and Drivers of Change for Ecosystems and Poverty in China

B1 – Underlying drivers of ecosystem change and poverty

This section summarises information on several of the major underlying drivers of change in ecosystems and poverty in China. The indirect and direct drivers which are considered to require more detailed analysis to achieve the aims of this study are examined in the other parts of Section B. These are global issues not solely restricted to China, and whilst full analyses are beyond the scope of this report, they are outlined below due to their importance in shaping the past and future state of poverty and the environment in China.

Population change

Since the 1970s China has formulated a state policy to promote family planning in an all-round to slow down population growth and improve population quality in terms of health and education. The Government encourages late marriage and late childbearing, and advocates the practice of "one couple, one child" and of "having a second child with proper spacing in accordance with the laws and regulations". Family planning is also advocated among the ethnic minorities.

After nearly 30 years of efforts the annual population growth rate decreased from 2.88% in 1970 to 0.55% in 2007. Since the implementation of the family planning program, over 300 million births have been averted nationally. Population growth in western China is above the national average (Shen, 2004). The total fertility rate of Chinese women has gone below the replacement level, making China one of the countries with a low fertility rate in the world. The average life expectancy increased to 72 years in 2005, the same as in medium-level developed countries.

China had a total population of 0.83 billion in 1970 and 1.32 billion in 2007. It is now forecast that the total population will be 1.40 billion by 2020, and 1.47 billion by 2050, which is less than previous forecasts of a peak of 1.6 billion by 2050. The urbanization process is accelerating with the rapid economic growth in China. In 1975, China's urban proportion of population was 17.8%, and in 2007 the urban proportion rose to 45.4%. Under a medium population growth scenario the urban population is projected to be 59.8% of the total by 2020, and 74.2% by 2050, when China will be a developed and urbanized nation.

In rural areas the reduced rate of population growth has lessened the local rate of increase in pressures for more land and demand for ecosystem services, whilst nationally increasing urbanization and per capita incomes are increasing the demand for ecosystem services within the country and from abroad.

Further data on population change in China is provided in Annex 7.

Economic growth

The economic development characteristics of China over the last 30 years are:

- Fast growth, with an average real GDP growth rate of 9.75% in 1979-2006. China's real GDP in 2006 was 13.34 times greater than in 1978.
- A stable economy and low inflation rate, averaging 8.29% for 1979-1996 and 2.09% for 1997-2006.
- Rapid growth in real GDP per capita in the last 20 years, which was 9.72 times as much in 2006 is in 1978. Current real GDP per capita is RMB 16,084 yuan or $2,217.

The growth of China's economy is expected to continue. According to data from the IMF, China's GDP per capita based on purchasing-power-parity (PPP) valuation of country GDP is expected to be $12,187 in 2010, reaching the level of Brazil and Mexico at that time; to be $21,092 in 2015, reaching then the levels of Russia and Malaysia; and to be $36,503 in 2020 and reaching the level of Argentina and Portugal at that time. Since 1995 China has formally made sustainable development a basic national strategy (Lu, 2007), including changing the mode of economic growth from high consumption of resources and high pollution to resource-saving and integration of economic growth and environmental protection, and to promote the development of high-tech industries (Yao, 2001).

Migration

According to a 1% sample survey (China Statistical Yearbook 1996-2007), China had a total

population of 1.31 billion in 2005. The floating or migrant population was 147.35 million (11.3% of the total), of which the inter-provincial floating population was 47.79 million. The major source regions of the inter-provincial movement are Sichuan, Anhui, Hunan, Jiangxi, Henan, and Hubei. The major destination regions are Guangdong, Zhejiang, Shanghai, Jiangsu, Beijing, and Fujian.

The main impacts of economic population migration on ecosystem services and poverty alleviation in China are:

- Through migration rural family income increases and thus rural poverty is reduced.
- Outward migration from rural China causes decreases in consumption of food, energy and other materials in rural areas and so reduces the local demand pressure for land resources and ecosystem services.
- China's rural to urban migration causes the increase of food, energy and living consumption in urban areas, which accelerates national food and energy imports, and thus transfer of the ecosystem demand pressure to global resources and ecosystems.

International and domestic markets

The development of domestic and international markets has been a major driver of change on ecosystem services and their management in China. For example, the expanding agricultural market from urbanization and economic growth has led to a shift from land intensive crops (wheat and rice) to labour intensive vegetable production in some eastern parts of the country; and China is now a net importer of wheat (Cosbey, 2006). Accession to the WTO, in combination with active domestic policies, could potentially see a shift away from farming marginal land. International markets can also have negative impacts on the environment, for example through the introduction of alien species (see Section B6). Some implications of China's huge forest product trade on livelihoods and ecosystems in China and internationally were mentioned by White et al. (2006). Further material on the 'ecological footprint' of China's wood consumption was collected by Zhu at al. (2004). In its forestry sector, China must face the combined challenge of meeting an increasing demand for wood and other forestry products while at the same time considerably raising its investment in forest-based environmental services (SFA 2002), an as yet unresolved incongruity between productive and environmental forestry (Weyerhäuser 2006).

The timber self-sufficiency index has decreased from 87.4% in 1996 to 49.1% in 2006. In 2004-2007, China's grain acreage and yield maintained four years of continuous growth. In 2007, grain output is expected to reach 501.5 million tons, which is 95.1% of the expected total consumption, 527.5 million tons, the major trend of international trade of agricultural products are increasing import of lower labour intensity and higher land intensity crops, such as oil seeds, pulse, cotton and sugar. Import of agricultural products is helpful for China to release its demand pressure on land and water resources.

Governance and land tenure

China has a large territory with complex ecological, geographical, and climatic conditions. The co-ordination of inter-related sectors and government departments is therefore vital and has a large influence on environmental management (OECD, 2006). Implementation of various policies has been said to be lacking (Swanson et al, 2001). This was also identified in an assessment of China's progress towards the Millenium Development Goals (MDGs), in which emphasis was placed on the need for research into the capacity of central and local government departments to co-ordinate and implement the schemes (China MDGs 2005). The capacity for local governments and people to implement policies is clearly related to their success in China (UN China, 2003)

One of the main governance factors is the allocation of land tenure. This has been identified as a crucial factor in the management of natural resources, both in the short term and to fulfill long term objectives (China Human Development Report; UN China, 2003). The need for clearly defined land and water rights to promote good resource stewardship in China has been identified (OECD, 2006). The majority of land in China is either state-owned or collective. An extension of this is the Household Responsibility System, whereby land is leased to farmers for a fixed period, a policy which has been extended to contracted grassland rights for herders. Although ownership of forest was meant to be transferred to individual household by forestry reforms, a significant portion of China's forests remains collectively managed. Zhang and Dai (2004) give a more detailed account of the reform system including tenure right aspects. According to official statistics, 44.4 million m^3 of commercial timber and fuelwood was produced domestically in 2002, of which 20.5 million m^3 or 46.3 % came

from collective forests (SFA 2003). Owing to the prohibitively high operational costs of managing smaller, non-contiguous plots, some areas which had been devolved to individual ownership were later returned to some form of collective management (Liu et al, 2001).

It has been estimated that strengthened land tenure could stimulate 200 million households to invest in soil and water protection (UN China, 2003). However, some issues over tenure security related to the short term nature of leases are said to be limiting this approach in China. Similarly, there are questions as to the impact of tenure on traditional nomad herding practices (Miller, 1999; Banks et al, 2003). Despite this, descriptive statistics in China suggest that increased forest protection and afforestation occurs when individuals have control and income rights over the land (Rozelle et al, 2000), rather than simple ownership of the collective (White et al, 2006; Grosjean and Kontoleon, 2007). Similarly, centralised and subsidy based environmental protection schemes are more readily implemented when there is individual ownership of land (Yang, 2004). The potential of land tenure to contribute to ecosystem management in China is still poorly known and requires research, but lack of property rights would appear to be an underlying driver that is not properly addressed through current policy. This is particularly prevalent given the current shift towards PES (see section B2), which requires clear demarcation of property rights (Yang, 2004). Further market reforms and policies may be needed to strengthen and secure the rights of collective forest owners and managers (Miao and West, 2004). Yet this aspect was not a priority topic during the EU-China Conference on Forest Law Enforcement and Governance (2007) in Beijing.

Public participation and environmental awareness

Another governance related issue is public participation in environmental management issues. (UN China, 2003), with a prevalence of top-down management schemes and a lack of integration of local socio-economic conditions with environmental management (OECD, 2006b; Liu et al, 2007). The priorities of the rural poor and the environmental protection goals of the government are not readily aligned, and an analysis of the complicated relationships together with local stakeholders is required for successful implementation of schemes. The capacity of policies to impact upon the household decision making with regard to resource use is largely attributed to addressing these underlying priorities.

Environmental awareness has also been identified as one of the driving forces of environmental improvement globally (UN China, 2003). However, the level of environmental awareness amongst the Chinese public has been very low (Swanson et al, 2001), with the average level at less than 20%, and this has been suggested to be a factor preventing the success of forest ecosystem service projects in rural China (Liu et al, 2007; Lee and Zhang, 2008).

Box-Key Messages

This section has very briefly outlined the larger processes at work in driving ecosystem change and management. The purpose was not to provide a thorough analysis of large-scale drivers, but to highlight their importance in relation to the issues discussed in the previous section. It is clear that there are many issues that need to be addressed to improve ecosystem management in China, and ecological factors are only one element that needs consideration in the broader social, economic, and political context. Whilst issues such as population growth and economic growth are far broader reaching than the scope of this study, the need for research into areas such as governance, land tenure, and socio-economic issues has been highlighted and is expanded upon in section C. An emphasis is needed to address the actual causes of poverty and environmental degradation in consideration of regional characteristics and patterns of resource use.

B2 – Major policies and programmes affecting ecosystems in China

As recognised in the Millennium Ecosystem Assessment (MA) and the Integrated Ecosystem Assessment of West China (MAWEC, 2005), government policy in China is the principal driver of change in land use and ecosystems and poverty reduction. China now has a comprehensive system of legislation, plans, strategies and programmes for addressing both environmental and development

issues, many of which are summarised in the Government White Papers[1]. Annex 7 provides lists of the government agencies most relevant to ecosystem management and poverty reduction, the major land-use and infrastructure projects impacting ecosystems, and the ten major ecological protection projects in the 11th Five-Year Plan. It is beyond the scope of this study to give a comprehensive overview of all relevant policies and mechanisms affecting ecosystems and poverty in China, but this section provides an introduction to several of the most significant policies and programmes. These are briefly described in the order of ideologies, strategies, policies and programmes. .

Conservation Culture

The report of the 17th National Congress of the Communist Party of China (CPC) in 2007 includes, for the first time, the strategic concept of "conservation culture", indicating that environmental protection has been streamlined into the main theme in China as a basic state policy. As a form of human civilization, the ideology of conservation culture includes both natural ecological issues and the spiritual issues of human being, promotes harmonious co-existence of man and nature. The conservation culture advocates an energy and resource-efficient and environment-friendly structure of industries, sustainable growth and consumption patterns, aiming at increasing the awareness of conservation of the whole society.

National Plan for Ecological Construction (1998-2050) and land use policy

In the 11th Five-Year Plan (2006-2011) and the National Plan for Ecological Construction (1998-2050) the Chinese Government aims to achieve 'ecological construction' to improve living standards, prevent environment degradation and reduce inequality and poverty. This is centred on the principles of taking a scientific outlook on development and building a harmonious society. Actions within the Plans include exempting farmers from agricultural taxes and implementing the Sloping Lands Conversion Programme. By the end of 2006 ecological restoration areas covered 670,000 km^2, including 29,000 silt-retention dams constructed on the Loess Plateau. Central government has invested approximately RMB 20.2 billion yuan from the central budget in poor regions for ecological construction, and more than RMB 77.4 billion yuan as fiscal transfer payment and special subsidies.

The land use policy includes strict protection of farmland from conversion to other land uses and to protect and improve the ecological environment and ensure sustainable land use. China's land space will be divided into four main functional zones: optimised development, key development, restricted development and prohibited development. The twenty-two restricted development zones include zones for biodiversity and ecological functions, and for erosion and desertification control. The prohibited development zone refers to all the types of nature reserves established by law. China's fiscal and investment policies will increase financial transfers to the restricted and prohibited development zones for public services and compensation for ecosystem services.

Western Development Strategy and Ecological Migration

The Great Western Development Strategy was initiated in 1999 to enhance both economic development and environmental improvement in western China (Xu et al, 2006). $8.4 billion is allocated for the acceleration of infrastructure development, improvement of ecological conditions, promoting industrial development, and strengthening science, technology, and education. The ecological component of the infrastructure development is focused upon water resources, reduced desertification and soil erosion, and improved flood control (Xu et al, 2006). The concept of 'ecological migration' has been recognised in Chinese policy since 2002, with the aim of reducing poverty by reducing the population pressure on the environment in ecologically fragile areas where human carrying capacity had been exceeded, and has been incorporated into the Western Development Strategy. Over the next 10 years, it is planned that there will be 7 million environmental migrants from nature reserves, and ecologically fragile zones, with a fund of RMB 3-5 billion yuan made available each year for their relocation. The government stresses that such migration should be combined with the major environmental policies, such as afforestation projects and restoration of grassland

The migration policy in itself perhaps logically stems from recognition that there are many areas of China in which the current and potential future populations cannot be sustained given the environmental conditions. However, Tan and Guo (2007) report that the lack of specific policies and direct compensation funds leads to difficulties in implementation, as does a lack of understanding of the actual number of people who will be displaced from each area and their socio-economic

[1] http://china.org.cn/english/MATERIAL/170393.htm

characteristics. This is largely due to a lack of knowledge of the number of people who are actually impacted by environmental issues and their spatial distribution. Relocations from the Three Gorges Dam, for example, have increased population pressure on over-cultivated sloping land, increasing the soil erosion problem. Equally important is the impact of displacement upon social and cultural networks.

Agricultural Policies

Intensive agricultural development was promoted in the 20th century through the policy of food self-sufficiency. Surpluses could be sold at controlled prices, but purchase of food through trade was prohibited. This strategy has been replaced with one of food security, but food imports are still low and agriculture is still encroaching on marginal land despite recent efforts to control this problem. In the period 1986-2000, land was converted to agriculture from grassland in northwestern and northeastern China, and large tracts of forest and wetland were also converted (Deng et al, 2006). Reclamation of wetland areas accounted for 82% of wetland loss (An et al, 2007), a significant proportion of which was for agriculture. Diversion of water for irrigation of agriculture is also exacerbating water shortage issues.

A study into agricultural production in China has revealed significant trade offs between economic, social, and environmental objectives; citing the large rural labour force with lack of employment opportunities as a major issue in programmes reducing agricultural output (Lu et al, 2004). Analysis of alternative policy scenarios on agricultural practices in Jinshan county has suggested that diversification of land use patterns promotes ecosystem improvement, and that government support for capacity and training are vital in sustainable development of agriculture. Limited information and high transaction costs are barriers to the adoption of sustainable farming practices by farmers (Shi and Gill, 2005).

Payments for environmental services (PES)

The concept of value assessment of ecosystem services has been launched comparatively recently in China, where traditionally there was a heavy reliance on state finance rather than market based instruments. Payments for environmental services (PES) have drawn great attention from the Central Committee of the Communist Party of China (CCCPC) and the State Council. On April 17, 2006, at the 6th Conference on Environmental Protection, Primer Wen Jiabao clearly stated that the policy and mechanism of PES must be established and improved based on the following principles: "Explorers should protect, destroyers should restore, beneficiaries should pay, and polluters should be charged fees". Many government policies in China, including in particular, the Resolution of the State Council on Implementing Science-based Development Perspectives to Enhance Environmental Protection and the Outline of the 11th Five-Years Plan for National economic and Social Development promulgated in 2006, had explicitly pointed out that eco-compensation mechanism should be established as early as possible. The scope of PES includes: the compensation for migration of residents living near the water sources or reservoir, subsidy to sewage treatment plants, investment in sanitation facilities, compensation for forestry sectors in the upstream including subsidy for non-commercial forests, sealing hillsides for forestation and afforestation, the subsidy of Sloping Land Conversion Planning(SLCP), compensation for regional development limitation, payment of farmers suffering from production loss for controlling non-point pollution and application of fertilizers and pesticides, etc. At present, the priority areas of PES in China are key ecological functioning zones, mining areas, watershed and some ecological factors such as forest.

The practices of PES in China, are carried out in different levels, from province to province, from city to city, from town to town, from village to village, from watershed to watershed. The sources of funding for such eco-compensation programs are normally from the government funds generated from the fiscal transfer payment with an aim of harmonizing the economic development levels of different regions and compensating those areas with high ecological significance and relatively less developed economy.

Grassland management

Due to the wide extent of grassland in China and the high levels of degradation the links between poverty and grassland management are a major focus in western and northern regions. In 2002 the Grassland Law was revised, placing emphasis on environmental protection and combating illegal grassland reclamation and medicinal digging (Wang et al, 2005). Investment in grassland from 2000-2002 amounted to RMB 2 billion yuan (about US$240 million). From 2004-2008 the state aims to

increase the area of artificial grasslands, improved grasslands and fenced grasslands by about 13.33 million hectares, 20 million hectares and 66.67 million hectares respectively. The Chinese government has launched programmes which subsidize herders to invest in grassland using different technologies such as fencing, planting artificial grass, irrigation and fertilizers (Yang and Hou, 2005).

A national grazing ban was introduced in the key pastoral provinces in 2003, under which 66.7 million hectares of severely degraded grassland in western China will be removed from grazing over five years. This means that 50 million sheep will have been banned from free grazing on the degraded grassland. In Ningxia, for example, all its 2.9 million sheep will be raised in fenced yards. In return, herding households will receive grain feed instead of cash. Official reports claim that the project has led to recovery of a large proportion of the vegetation in the initial stages, and RMB 26 billion yuan will be invested in the project to 2010 (Wang et al, 2005). However, it has been suggested that more investment in farmer subsidies and capacity building is required to offset the loss of livestock production.

Existing research on grassland degradation focuses in particular on technical solutions, with little attention paid to the institutional and policy driving factors of herders' behaviour and the resulting in environmental effects (Ren, 1992; Zhu, 1997; Liu et al., 1998; Wang et al., 1999; Huang and Wang, 1992; Li and Zheng, 1997; Wang et al. 2003; Yang and Shao, 2000; Hu et al., 2002). This may explain why the degraded grassland area is still expanding at a rate of about 2 million hectares per year, despite the huge efforts made by the Chinese government at different levels to control grassland degradation (Ho, 2000; Chang, 2006). Banks et al. (2003) considered that given the social and ecological context of pastoralism in western China, the continuation of collective and group tenure and management is appropriate, rather than the household tenure model emphasized in grassland policy. They argue that grasslands are by nature extensive and with a low productivity per unit of area, and spatially and temporally variable. This makes the benefit of establishing household grassland management through fencing marginal at best, and is more economically achieved through group tenure arrangements. Lintai (2005) argued that some of the theories on which policies for grassland management are made in China need re-evaluation. The mainstream theory is based on regenerating grassland by decreasing the number of livestock that graze on each unit of grassland (adjusting animal carrying capacity) to levels where grass will regenerate. This has resulted in policies such as banning grazing, fencing grasslands to exclude livestock, and rotational grazing plans. Lintai (2005) investigated grassland enclosures in Inner Mongolia that had not been grazed for 30 years and found only a few shrubs and extensive bare ground and erosion. He concluded that grassland in that region without any utilisation degrades and loses productivity, with livestock and wild herbivores a key part of the ecosystem and grassland regeneration. Jiang (2006) examined why tree planting and grass seeding in a grassland area of Inner Mongolia produced increased incomes, but also resulted in grassland and water table degradation, and concluded that 'ecological construction' had been conducted with a lack of attention to or understanding of the local ecological processes and properties, such as the water cycle.

Aside from natural causes, the lack of communication and coordination among decision-makers, researchers, business, NGOs and herders also contributes to the problem. It is argued that grassland management can only be successful if technical, legal, and institutional problems are addressed simultaneously (Ho, 2000). However, few empirical studies are available to examine the driving forces of degradation, where grassland management is seen as a system and herders seen as main stakeholders.

Afforestation

China's 'ecological construction' policy has focused heavily on afforestation, with 6.6 million hectares of forest per year planted under various projects since 2002 (White Paper, 2006), many of which fall under the SLCP (Jun, 2006). The Loess Plateau has been one of the main areas targeted for afforestation projects, which have reportedly led to an improved microclimate and regulation of wind driven sand damage and desertification (Wang et al, 2003).The Three North Forest Shelter Belt project, initiated in 1978, is the earliest afforestation example (Xu et al, 2006). The project has been reported as successful in some areas, but overall has not delivered envisaged results, with survival rates of planted trees mostly below 50%, sometimes as low as 10% (Yang, 2004). A lack of knowledge of hydrological processes at site, landscape and catchment scales has been noted as an issue in re-vegetation projects, particularly as water has been identified as the commonest limiting factor for

China's terrestrial ecosystems. From a water availability perspective, a literature review reported reduced annual streamflow in association with afforestation in 12 of 13 case studies (McVicar et al, 2007). It has been noted that evapotranspiration of trees is higher than that of shrubs and herbaceous plants, and the afforestation of semi-arid areas could potentially aggravate drought (Liu et al, 2004). The lack of diversity in plantation forest results in the provision of more limited forest ecosystem services than natural forest (UN China, 2003), although it is not known what the impact will be on a large scale in China. Artificial forests in the Hexi Corridor are also showing signs of degradation, with desertification spreading at a faster rate than plantation forest around important desert oases (Wang et al, 2003). Plantation forests also have a lower capacity to intercept sandstorms and stabilise soils than grassland, suggesting that a focus on forest plantations could potentially not be the most cost-effective and efficient method of land restoration (Liu et al, 2004). Negligence of maintenance and inefficient management were common reported problems. From a socio-economic perspective, there have also been reports that afforestation schemes have led to abandonment of livestock production, leaving farmers to rely on less lucrative cash crops such as tea. (He et al, 2003). The combination of the SCLP and NFPP programmes, for example, greatly limited the NTFP collection and land for traditional herding (Weyerhauser et al, 2005).

Sloping Land Conversion Programme (Grain for Green)

(See Annex 8 for a more extensive review of socio-economic and ecological aspects of the SLCP). The Sloping Land Conversion Programme (SLCP) has the objectives of poverty alleviation and reducing soil erosion and flooding. It promotes returning farmed land on steep slopes to forest or grassland by giving compensation to farmers who plant trees and grass,. It is the biggest ecological construction project in China, with the highest levels of public participation, and was initiated in 1999. The SLCP is intended to be a voluntary scheme farmers receive annual compensation for loss of agricultural production (provisioning ecosystem services) of 100-175 kg of grain per mu[2], RMB 20 yuan per mu to increase access to health and education, and RMB 50 yuan per mu for seedlings or saplings planted, as well as free seedlings or saplings in the first year (Weyhaueser et al, 2005). The ten-year programme aims at converting 32 million hectares of bare or cultivated sloping land into forest or grass land, with a budget of over US$30 billion and affecting 60 million households, making it one of the largest land-set aside programs in the world (CCICED, 2006; Xu et al., 2006).

Ecosystem management tools being used by the SLCP are the plantation of trees or grass and using rest through cessation of farming and exclusion of grazing. Where farmland is taken out of production there can be a negative impact on the provisioning ecosystem services of food production. Where sloping agricultural land is converted to grassland the provisioning ecosystem services of crops may be replaced by livestock production. Uchida et al. (2007) suggested that much of the freed-up labour from cultivation and SLCP compensation has been used to build up livestock. Xu et al. (2006) consider that, "mostly the benefits of the SLCP derive from the effectiveness of the programme in being able to aid in the reduction of the build up of silt in irrigation networks and reservoirs and the reduction in downstream flooding. According to the work of MacKinnon and Xie (2001), the benefits could be as great as RMB 3.9 billion yuan per year in foregone soil loss. Ning and Chang (2002) have estimated that the value of reducing soil erosion in net present value terms would be more than RMB 50 billion yuan. Uchida et al. (2007) state that under the SLCP "most observers agree that soil erosion has been greatly reduced", although evidence for this was not provided.

The primary objective of the SLCP is ecosystem restoration rather than poverty reduction, and of 180 counties with the SLCP in 2004, 104 were poverty counties (Li, 2003). More than 52 million people are estimated to have benefited from the project, and a study found that five out of seven counties assessed reported satisfaction levels of over 90% with the SLCP and an improvement in farmer livelihoods (Xu et al, 2006). Uchida et al. (2007) concluded that the SLCP has been moderately successful in achieving its poverty alleviation objectives and they found that income from livestock activities and other assets of SLCP participants have increased significantly more than those of non-participants (due to programme effects). An assessment of the social sustainability impacts of SLCP showed it to have brought RMB 23.56 million yuan in net income to one million peasants of Zhangye Prefecture, in the Heihe River Basin in Northwest China (Peng et al, 2007). Between 2002 and 2004, an estimated total of RMB 190.59 million yuan of household income was generated for all rural households involved in the project in Zhangye.

[2] 1mu=1/15ha

National Forest Protection Programme

The National Forest Protection Programme (NFPP) was initiated alongside the SLCP in 1999 following the devastating Yangzte River floods of 1998 (Zheng et al, 2001). The aim of the NFPP is to protect natural forest with emphasis on the regulating services of soil erosion prevention and flood control, through reduced logging in the upper and middle reaches of the Yangtze and Yellow Rivers, and to shift the emphasis from logging to afforestation. 61.1 million hectares of natural forest and 33 million hectares of state owned forest are covered by the programme, which aimed at the outset to reduce logging by 12.4 m^3 every year to 2010, and to afforest an area of 8.67 million hectares (Cohen et al, 2001). Targets for logging bans and resource protection in natural forests have largely been met (SFA, 2003 in Xu et al, 2006; Zheng et al, 2001) although the NFPP did not have explicit poverty reduction goals (Xu et al, 2006).The programme now covers 17 provinces (Liu et al, 2007). It has been reported that the total investment in natural forest protection from 2000-2010 will amount to RMB 96.2 billion yuan (Jun, 2006), on top of the RMB 22.62 billion yuan spent from 1998-2000 (Xu et al, 2006).

The ecosystem management tools employed in the NFPP were largely rest from disturbance and tree planting, and the programme had obvious ecological benefits in terms of conserving natural vegetation. However, land use rights were not properly established, resulting in low investment of conservation practices (Xu et al, 2006). Similarly, decreased or terminated logging quotas have had an obvious impact on village communities (Weyerhaueser et al, 2006). A recent economic assessment of the NFPP (Xu et al, 2006) suggested that local farmers in communities surrounding natural forest have suffered a severe reduction in income (Xu et al, 2006). This is particularly true for the poverty stricken mountainous areas dependent on forest protection, who have reportedly not received sufficient government support (Zheng et al, 2001).

Major water diversion projects

Water availability is one of the most limiting factors in the terrestrial ecosystems of China (Wang et al. 2003), and there is a great regional imbalance in water supply, with much higher availability in the south and scarcity in poverty stricken regions of the north. In response to this, China has several major water diversion projects, the largest of which is the South-North Water Transfer Project which connect four major rivers including the Yangtze River, the Yellow River, Huai and Hai River. According to the project plan, the project will transfer t about 44.8 billion m^3 of water by the end of 2050 (MWR, 2000). In order to secure the water supply of Beijing, 46 million m^3 of water was diverted from Shanxi and Hebei provinces. To ensure water supplies and reduce salinity for the cities of Macao and Zhuhai an emergency water diversion from the Pearl River Basin was conducted.

To increase water use efficiency, there appears to be much scope for research into controlling the demand side, such as water wastage prevention policies and technologies, as well as the use of less water-intensive agriculture, which have the potential to increase northern water resources by similar volumes to that of the south-north water transfer (OECD, 2006). Reducing the pollution levels of northern rivers could also be a cost-effective strategy.

Dams

Due to the importance of water for both industry and agriculture, there have been major investments in dams in China. By 2006, 85,849 reservoirs of all kinds had been constructed, with a total storage capacity of 584.2 billion m^3, of which 482 were large reservoirs, with a total capacity of 437.9 billion m^3 (China Statistical Yearbook 1996-2007). The largest development is the Three Gorges Dam on the Yangtze River (Tan and Yao, 2006), which was built for flood control, water regulation, and electricity production. Its 17GW hydropower capacity will contribute an estimated 7% of China's power needs, and increase water storage capacity by 13% (Varis et al, 2001). However, it is likely to have a significant impact upon many other ecosystem services (Wu et al, 2004), such as food provisioning, regulation and cultural services of the flooded area, as well as similar impacts on areas where displaced populations put added pressure on the environment. The dam required the resettlement of millions of people (Tan and Yao, 2006).

The provisioning fish services of wetland ecosystems in China is overlooked in the literature, and similarly research into impacts on such services appears to be ignored in dam development. Dams block spawning migrations and reduce recruitment; the Gezhouba Hydroelectric project reduced the rate of recruitment of the Chinese Sturgeon, a major economic species, by 80%. (Chen et al, 1996), and the storage capacity of this dam has been reduced by 44% after only seven years in operation (Tan

and Yao, 2006). Similar impacts on river seasonal flow dynamics have been noted for the Three Gorges Dam, with large potential impacts on downstream biodiversity in a river that provides over half of China's fish production (Tao and Yao, 2006). Dam construction and water diversion also impacts natural wetlands, which have natural flood control and water provisioning capabilities (An et al, 2007), isolating 70% of natural wetlands from river sources.

In terms of livelihood impacts, the Three gorges Dam has also inundated many cultural sites and relics (Tan and Yao, 2006), which have been relocated or destroyed; the largest being the relocation of the Zhang Fei Temple, which dates from 220 A.D (Ponseti and Lopez-Pujol, 2006).

Box—Ningxia Case study

A major programme of regional economic development and 'ecological construction' is being implemented in Ningxia, including the Sloping Lands Conversion Programme and supporting voluntary resettlement from poverty stricken areas to more productive lands. Measures include improving irrigation efficiency and capacity from the Yellow River, watershed management through afforestation, grazing bans and confined livestock raising, grassland reseeding and building catchment dams, tree planting for windbreaks, and supporting off-farm employment. As a result vegetation coverage on the steppe and desert grasslands has increased by 50% and 20% respectively, and grass production on these lands increased by 30%. Moving sand dunes have been reduced from 80,000 ha to 13,000 ha. The total number of sheep has increased by 29% since the grazing ban to 10.55 million. Agricultural industrialisation and irrigation have stabilized grain production at 550 kg/person, achieving food self-sufficiency. Biogas tanks, solar cookers and water heaters and wind turbines have reduced straw and wood for fuel by 100,000 tons. From 2000 to 2006 the number of absolute poverty-stricken and low-income people reduced in Ningxia by 462,000 and 435,000 people.

(Source: Ningxia Commission of Development and Reform (2008) Strategic Studies on the Ecological System Beneficial Cycle and Poverty Reduction in Ningxia – Report for the China ESPA Project. 54 pp. See summary in Annex 4)

Protected Areas System

The protected areas system includes the construction of nature reserves, protected eco-areas, and places of historical interest and scenic beauty. By the end of 2005, there were 2,349 nature reserves of various kinds and levels in China, covering 1.5 million sq km and taking up about 15 percent of the country's land territory (Environment White Paper, 1996-2005); the State has started eco-area construction in the areas of river headwaters, and areas important for preserving water sources, river flood storage and buffering, sand fixing with windbreaks, and other ecologically important areas. So far, 677 places of historical interest and scenic beauty have been approved by the Chinese government, among which 187 are national-level ones (Environment White Paper, 1996-2005). Despite increase in coverage, there has been insufficient assessment of the status of the protected areas, and management capacity is lacking (OECD, 2006).

Green GDP

The Chinese government has begun to design mechanisms which are expected to prevent government officials from continuing the single-minded pursuit of gross domestic product (GDP) growth and help them to realise the government's environmental goals. The green GDP campaign is the new policy orientation. On the 7th September, 2006 State Environment Protection Administration (SEPA) and National Bureau Statistic (NBS) together published the "China Green National Accounting Study Report 2004" （SEAP, 2006a） and announced the first green GDP, a GDP index with environmental losses taken into account, and claimed that it was the first time that any nation's government had succeeded in such a project (SEPA, 2006b). The report has calculate the environmental pollution cost China RMB 511.8 billion yuan (about US $64 billion) in economic losses, accounting for 3.05% of 2004 GDP. The environmental costs of water pollution, air pollution and solid wastes and pollution accidents accounted for 55.9%, 42.9% and 1.2% of the total costs respectively. It also estimated that to treat this pollution, China would have had to spend as much as RMB 287.4 billion yuan, equivalent to about 1.8% of the GDP in 2004 (SEPA, 2006c).

International policy drivers

Environmental issues in China have a strong international significance due to the regional nature of transboundary air, land and water issues OECD (2006). China are signatories to the following major Multilateral Environmental Agreements: UNCCD, CBD, UNFCCC, CITES, and also to the WTO, which has significant implications for trade and therefore domestic policy. However, low capacity is reducing the potential of China to effectively implement these international agreements and there is little analysis of their impact (OECD, 2006).

Box-Key Messages

The policies and programmes reviewed in this section are all large scale and more research is needed on their impacts on poverty, ecosystem services and ecological processes. Reports of project success seem to be backed up with very little socio-economic and environmental data. This is a requirement if 'joined up' policy making and learning from successes and failures (adaptive management) is to be achieved. The current emphasis solely on restoration of ecosystems of some policies has been deemed by some to be impractical (Wang et al, 2003). There appears to be a lack of co-ordination between agencies, and social costs are not properly assessed (Xu et al, 2006). Wide-scale policies are not always applicable in a country with such variation in climate and geography. More research into the potential for terraced agriculture and livestock management to improve environmental conditions (Ye et al, 2003), for example, might be more applicable than afforestation in some areas.

It has been suggested that land management projects in China are initiated without consideration for the drivers of natural resource degradation, ignoring social and institutional issues (Yang, 2004; Wang et al, 2003). For example, although an estimated RMB 150 billion yuan will be invested in the conversion of farmland to forest over the next 10 years, there is little emphasis on the underlying social and institutional drivers of resource management problems (Yang, 2004); and changes in land use alone are unlikely to be an effective measure to overcome water deficiency in China (Cao et al, 2007).

B3 – Valuation of ecosystem services

After Costanza published his well-known paper entitled "The value of the world's ecosystem services and natural capital" in Nature in 1997, Chinese ecologists have carried out a series of similar research and valuation studies at different scales and for various types of ecosystems. In particular, many valuation studies have been done at the national scale of China. For example, Ouyang et al. (1999) estimated a minimum value of Chinese terrestrial ecosystem services of RMB 3.04×10^{13} yuan including organic matter production, carbon dioxide fixation, oxygen generation, nutrient storage, soil and water conservation, and air purification. Others have found similarly high values of RMB 4.5×10^{12} yuan (Chen and Zhang, 2000) and RMB 9.17×10^{12} yuan (He et al., 2004) for terrestrial ecosystem services across China.

Additional studies have focused on particular ecosystem types, mostly associated with forest, grassland, and wetland ecosystems (Zhao et al. 2004a; Zhao et al. 2004b). Selected studies have been carried out at more local and regional scales (i.e., provincial or regional scale) and on particular services, notably hydrological services. Geographic foci have included forest services in Shannxi (Kang et al., 2005), grasslands in Qinghai (Min et al., 2004), wetlands in Panjin County (Xin and Xiao, 2002), the Black River Basin (Zhang et al. 2001), and Hainan Island (Ouyang, 2004). For hydropower benefits, Guo et al. (2001) found intact watershed forests were worth RMB 5.05×10^6 yuan/yr to the Gezhouba hydroelectric power plant in Hubei Province.

Overall, ecosystem service valuation studies in China have focused on large-scales and direct use valuation for single scenarios (Zhao and Yang, 2007). The majority of the studies have proved useful in informing the public and governments that ecosystem services have significant economic value; however, actual incorporation of these values into programs or policies is lacking. Because of data variability, results too have been highly variable and thus have not garnered the credibility necessary

for effective policy influence. Large scales are too big for regional scale ecosystem management, static valuation snap-shots do not capture critical dynamic changes across multiple scenarios, and over-reliance on direct use values limits broader appreciation for the full suite of ecosystem services on which humans depend (Zhao and Yang, 2007).

Basis of Payments for Ecosystem Services

Though valuation studies are numerous, and many eco-compensation[3] and Payment for Environmental Services (PES) projects already exist across China, there is no clear linkage between the two and no clear standards for determining payment levels. While compensation systems are supposedly largely designed based on costs to service producers such as direct economic loss of farmers from reforestation (Hang et al., 2002; Liu et al., 2007), in actuality the final compensation amounts rarely follow those guidelines (Liu et al. 2007). Selected programs have some scientific basis for payment amounts, such as the Grazing-to-Grassland restoration program in Ningxia where 1 mu of retired land is exchanged for 100 kg of grain plus RMB 15 yuan/yr in seedlings; however, other programs are less clear.

One of the earliest transactions to support provisioning of water supply occurred in 2000 between Yiwu and Dongyang cities in Zhejiang County for RMB 200 million yuan, plus annual costs of RMB 5 million yuan, an amount determined by direct negotiation between the two parties.

Large government programs also wrestle with this challenge. The Forest Ecosystem Compensation Fund provides RMB 5 yuan/mu for protection of watershed forests for forest services, an amount largely derived from willingness and ability of the State to pay after nearly a decade of discussion, negotiation, and multiple rejected proposals (Sun and Chen, 2002). The actual amount is below the forest tending costs of roughly RMB 10 yuan/mu/yr, only subsidizes forest management, and is considered low in terms of opportunity cost of alternative uses. On the other hand, the Sloping Land Conversion Program has been vigorously subscribed to at least in part because of their generous payments for reforestation of agricultural lands to improve water and soil retention that amount to 15 times the average per hectare rental payment (in Purchasing Power Parity) of a similar Conservation Reserve Program implemented in the United States (Uchida et al., 2005).

More straight-forward are carbon payments, as China is signatory to the Kyoto Protocol. A single Clean Development Mechanism project for reforestation has been approved in China and awaits a buyer on the international market through market-driven prices for carbon. In fact, compensation schemes now focus largely on direct payments for such services as carbon sequestration or water supply. Indirect compensation can and should be explored further, as well as non-economic valuation that may better reflect how the poor value their most critical ecosystem services. More information on PES in China is presented in Annex 9.

Linkages with Poverty

Payment schemes have significant potential to alleviate poverty by encouraging environmentally-friendly management activities in exchange for "rewards" structured mostly through direct government payments or more market-based mechanisms in China. Transferring of funds from, for instance, wealthier downstream beneficiaries to poorer upstream ecosystem service providers, can alleviate poverty since many poor are found in remote, mountainous areas. Successful PES needs to clearly identify who pays, how much, to whom, for what, and for how long (Daily 2007). Eco-compensation programs would be significantly enhanced by:

- better understanding of ecosystem service flows revealing suppliers and beneficiaries and therefore potential buyers and sellers of services;
- development of eco-compensation guidelines and standards for setting of payment values;
- understanding of cause and effect linkages between ecosystem conservation and management and the provision of ecosystem services to beneficiaries (World Bank, 2007);
- better understanding of trade-offs among different values. Transparent standards easy to understand for both service suppliers and beneficiaries support compensation schemes, and would help to ensure sustainability of existing schemes.

[3] Eco-compensation is any compensation for environmental damage to livelihoods or for ecosystem service supply

B4 – Impacts of pollution and over-exploitation

The tremendous growth of China's economy since the 1978 reforms and population growth are the major ultimate driving forces behind the pollution that the country suffers from. As in Europe or the United States in the 1960si, the emphasis has been on economic development and competitiveness, which in China was supported by the integration of surplus workforce from agriculture in more productive sectors. In its recent environmental performance review to examine the progress between 1990 and 2006, OECD (2007) made recommendations for better control of environmental pollution and resource over-utilization: "Special provisions are needed to integrate environmental management into the development strategies and ensure the affordability of environmental services for the poor." CAEP (2006) computed 'environmental pollution costs' (= cost equivalent estimates for prevention or mitigation) at RMB 511.82 billion yuan around 3.05% of the 2004 GDP. Water-related pollution (55.9%), ranked highest among such costs, followed by air pollution (42.9%), and solid waste and accidents (1.2%). For a more comprehensive overview of different kinds of pollution, the reader is referred to the environmental statistics (SEPA, 1996).

Water pollution

Average water quality classes along major rivers are shown in Figure B4.1(b). Chronic water pollution may result in greater losses than those caused by acute toxicity. The resulting changes in the biological community can affect the ecological balance of the whole water body. Due to the lack of research on the relationship between water pollution severity and fish growth and reproduction, chronic damage is hard to estimate, so a rule of thumb ratio of 3:1 indirect to direct losses is applied (MOA, 1996). In 2003 the damage to inland fisheries was estimated at around RMB 1.2 billion yuan (MOA and SEPA 2004). The main types of water pollution are nitrogen, phosphorus, petroleum, and heavy metals, but other substances like endocrine disruptors also take effect (An and Hu, 2006). In the last decade there were significant achievements in meeting industrial discharge targets of harmful substances, but the reduction of COD was less successful and modest gains were offset by increases from municipal sources (World Bank and SEPA, 2006). To curb industrial pollution further SEPA now promotes financial instruments like 'green insurance' and 'green credit' (Sun, 2008). Irrational use of fertilizers and pesticides in agriculture contributes to the impairment of water ecosystems and human health while reducing farmers' income (Huang et al., 2006). Addressing agricultural non-point source pollution requires deriving reliable load estimates and developing a strategy with consensus of the relevant parties, among which agricultural extension should take a leading role. Research must support this by developing more efficient use, reuse and recycling of agricultural inputs and outputs (Zhang and Zhu, 2005; Zhang et al., 2005; Tang and Yin, 2006).

Air pollution

From the nationwide air quality monitoring network, around 60% of China's cities above county level met Grade II ambient air quality standard by 2005. The three grades (classes) described in the Law on Prevention and Control of air pollution set maximum concentrations of hourly, daily, and annual averages of ten pollutants, like SO_2, CO, NO_x, and lead. These are complemented by maximum emission targets for particular landscape categories. More than 85% of SO_2 in China comes from combustion of high sulphate-content coal. Despite successive modernization of power plants and the expansion of alternative sources of energy, acidification by SO_2 is likely to remain a problem if GDP growth remains as high as expected. The same holds true for CO_2-emissions, which can be buffered by expanding forests, but relative to emission trends of the industrial and energy sectors, net carbon uptakes decreased under all modelling scenarios (Zhang and Xu, 2003), showing the need for further mitigation policies. Paradoxically, SO_2-emissions and the resulting formation of sulfate particles slow down global warming as aerosoles reflect sunlight back to space (Crutzen, 2006). Damages to vegetable crops from SO_2-emissions in China were estimated at 24 billion RMB in 2003 (World Bank and SEPA, 2007), but more evidence is needed to sustain the estimate. Effects of SO_2 on forest productivity are uncertain since nitrogen deposition, increasing temperature and carbon dioxide concentration (Fang, 2000) can have stimulating effects.

Over-exploitation of natural resources

Major aspects of this topic were mentioned in Section A3 (Supply of ES), so here we only complement this with some more information on water resources, which are already constraining economic development in China, while being at the same time crucial to food security. Amplified by population growth until 2040 this results in conflicts relevant to poor land users, who need water as an

insurance against drought. Poverty is a powerful driver of resource over-exploitation, fuelled by the need to survive under scarcity. Water scarcity is a state in which "the amount of water withdrawn from lakes, rivers or groundwater is so great that water supplies are no longer adequate to satisfy all human or ecosystem requirements, bringing about increased competition among potential demands." (http://freshwater.unep.net). Less than 1,000 cubic meters annually per person indicates extreme water scarcity (Falkenmark 1997), a condition for which about one third of China's provinces qualify (Fig. B4.1(a)). In Beijing, Hebei, Ningxia, Shanxi, and Tianjing per capita water resources even fell below 500 cubic meters (NBS, 2004). In the Yellow River basin, where agriculture and poverty prevail, the amount of water-withdrawing capacity has exceeded the available amount of natural runoff (Liu and Xia, 2004). What remains is mostly far below ecosystem flow requirements as defined by Smakhtin et al. (2007) or Sullivan et al. (2006). The World Bank and SEPA (2007) have estimated the amount of polluted water held back from supply in water scarce basins by estimating the amount of unusable water resources (water quality class IV or worse) as a share of total available water resources. Ningxia-Hui Autonomous Region has zero non-supplied polluted water. The situation is so tight that all available water resources, including polluted resources (around 4 billion m^3), are used in supply and the marginal cost of water is very high there (Liu and He, 1996). In China, more efficient water use in agriculture, which consumes 65% of the total, is vital to ease the problem of water scarcity. Water-saving technologies and management, tradability of secure water rights, water-user participation, and water tariffs which better reflect the costs of resource use need to be promoted (Liu, 2006).

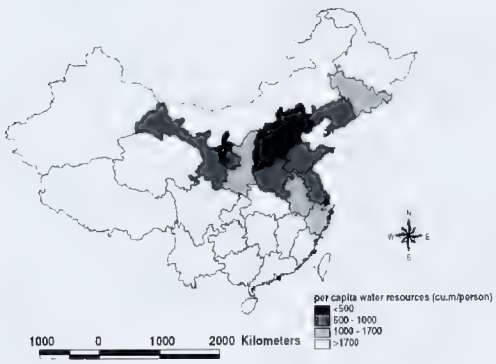


Figure B4.1 Available per capita water resources of Chinese provinces (from World Bank and SEPA 2004; data based on 2003)

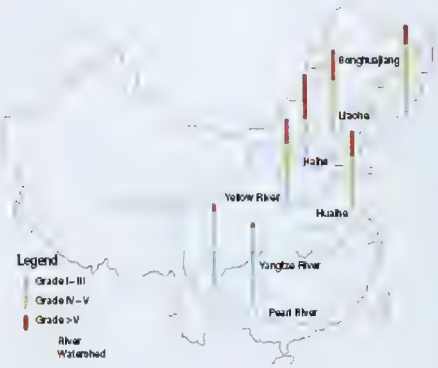


Figure B4.2 Water quality of seven major rivers in China. (from Shao 2006); national surface water quality Standard: water of grades I–III suitable for drinking, grade IV for industrial use (no body contact), and grade V for agricultural use

B5 – Potential impacts of climate change on ecosystem services in China

Climate change is projected to have significant effects on China's ecosystems, and is therefore likely to impact upon the status and distribution of ecosystem services. Assessment of such impacts is vital in order to identify regions in which adaptation to climate change could be a priority. The potential impacts of climate change on China's ecosystems have been modelled as part of global and regional impact models, at both national and subnational scales. Alpine areas are particularly vulnerable to climatic conditions, and montane ecosystems have therefore received particular attention.

Most published research on this topic focuses on biophysical effects such as changes in climate variables, and on consequent possible changes in potential vegetation, rather than on quantifying the subsequent impact on ecosystem services. However, there is a considerable literature on the direct impacts of change on agricultural and water services (Annex 10). This review summarises the state of knowledge on the likely impacts of climate change on China's ecosystems, species, carbon storage,

water supply, and crop production. Further details on individual studies may be found in the annexed tables.

Projections of climate change in China

The most recent global scale scenario modelling undertaken for the Intergovernmental Panel on Climate Change was released in 2007 as part of its Fourth Assessment Report (Solomon et al., 2007). For scenario A1B, the suite of models used generally agree on the direction of changes in the frequency and volume of rainfall in China, and the relative extent of warming. Under the B2 emissions scenario adopted for assessments by the National Climate Change Centre (NCCC), regional models project that the average temperature for China as a whole would increase by 1.2°C, 2.2°C and 3.2°C during the periods of 2011—2020, 2041—2050 and 2071—2080, respectively (Wu et al., 2007). Regional climate models developed for the IPCC and by other Chinese scientists agree that, whilst significant regional variation can be expected, greater increases in temperature are likely in the north than the south (Chen et al., 2006; Guo et al., 2002; Xu et al., 2006a; Lin et al., 2007).

There is much less agreement between models about the magnitude of the increase in precipitation that is expected. The monsoon system strongly influences the weather patterns in China, and its interaction with the El Nino Southern Oscillation cycle is complex to model. For example, a model using seven IPCC scenarios projected a precipitation increase of 0.7 - 6% for the north of China, a large range of uncertainty (Huang et al., undated). The Max Planck Institute (MPI) model projects a 1.6% average increase in precipitation in the north (Guo et al., 2002), and the NCCC projects that precipitation will increase by 4%, 7%, and 10% in 2020, 2050, and 2080, respectively. Increases in precipitation may be especially strong in the north of the country and in the winter months, and regional climate models also simulate a higher incidence of extreme events. In South China, it is anticipated that the number of days of rain will decrease, but that the number of days of heavy rain will increase. In Tibet, precipitation seems to increase all year round. Heat-waves are expected to become more frequent, and severe cold spells less frequent.

The mountainous regions of Northern China have already seen a temperature increase of 0.7°C over the last 40 years (IPCC, 2007); a significant rise (0.5°C) having been recorded over the Qinghai-Tibetan Plateau (QTP). Tibet is projected to warm by 3.8°C by 2100, a greater increase than the global average (Christensen et al., 2007); the East Asia region that includes most of the rest of China has an average projected increase of 3.3°C. The additional warming in the QTP is as a result of the melting of snow and ice, and hence a decreased reflectance of incoming sunlight.

Potential impacts on terrestrial ecosystems

Ecosystems can be modelled in two main ways; a large number of distinct ecosystems can be simulated on the basis of correlations with present climate, or a smaller number of ecosystems can be modelled taking account the physiological response of plant functional types (PFTs) to increasing atmospheric CO_2. When the PFTs are simulated within a dynamic global vegetation model (DGVM), some of the processes of lag in the response of vegetation to change are also simulated. However, models rarely consider non-climate limiting factors to vegetation spread such as soil type, or species' dispersal limits (Pitelka et al., 1997), and the first approach may overestimate the vulnerability of ecosystems to increasing aridity. No comparisons of the results of these two approaches were found in the literature, but both types of ecosystem model simulate extensive change in the spatial distribution of China's ecosystems in response to expected degrees of warming. On a global scale, this issue could be particularly acute in Northeast China, where substantial turnover in biomes is simulated by multiple models at doubled CO_2 levels (Malcolm et al., 2002).

The BIOME3 model simulates the influence of climate and CO_2 on vegetation. At doubled CO_2 levels, it simulates replacement of half of the mixed temperate forest of north-eastern China with broad-leaved temperate forest, as well as some invasion of the high altitude ecosystems in western China by conifer forests (Ni et al., 2000). At tripled CO_2 levels (and using the GENESIS rather than the Hadley GCM), BIOME3 projects a greater increase in the area of forest, especially in the south and west of the country (Kutzbach and Behling, 2004). Large areas of grasslands and savannas give way to temperate forests, and temperate forests to tropical. This type of model does not include direct human influences on vegetation or the lags in the response of vegetation to change, and is therefore indicative only of what has the potential to grow in the absence of land use and at equilibrium.

Projections of future climate may also be used to map future Holdridge life zones, representing

equilibrium response to climate. Under a doubled CO_2 simulation, large shifts in Holdridge life zones were observed, with changes over 89% of the land surface (Chen et al., 2003). The total area of forest increases by ~15%, with decreases in desert and Tibetan Plateau vegetation. Similar projections undertaken using three of the IPCC's SRES (Special Report on Emissions Scenarios), and applying likely land uses to Holdridge classes, also identified an increase in the area of forest (woodland) and decreased snow cover, but saw warm desert areas increase (Liu et al., 2005; Yue et al., 2006; 2007). In general, this is a response to increased temperature, precipitation and potential evapotranspiration.

Species biodiversity

The global IUCN Red List names seven species native to China for which climate change is thought to be a major threat: three bird species, three amphibian species and a single species of fish, mostly limited to montane habitats. These species and are listed on the basis of expert assessment, as few formal studies of the likely impact of climate change on individual Chinese species are available. Exceptions include an investigation of impacts on Korean pine (Xu and Yan 2001), which indicates a likely decline. It is very likely that species in high mountain ecosystems such as high alpine meadows will decline as a result of a warming climate. The extent and speed of the ecosystem shifts simulated by biome and vegetation models indicates that many other species are likely to be at risk. It appears that this is a major gap in the literature; there are suitable data for some taxa, and a number of studies of the influence of climate variables on species richness in China (Li et al., 2006).

Primary production and climate regulation through carbon storage

Carbon sequestration and storage in ecosystems is thought to have a complex response to changes in precipitation, temperature and atmospheric CO_2 levels. There is more uncertainty related to factors influencing storage of carbon in soils than vegetation, as soil respiration is directly influenced by climate. In recent decades, the mean national net ecosystem productivity (NEP) has been declining, mainly in response to high temperatures (Cao et al., 2003), but also being influenced by pressures such as ozone pollution (Ren et al., 2007) and nitrogen deposition (Ju et al., 2007). This masks regional differences: decreases were seen in northern ecosystems, in which climate was warming without additional precipitation, and increases in southern ecosystems, in which precipitation did increase.

Projection of net primary productivity (NPP) on a national scale using the BIOME3 vegetation model under a doubled CO_2 climate indicate a likely future increase in carbon storage within native ecosystems (Ni et al., 2000; Ni, 2001). A recent physiological model for forest also indicates likely increased NPP under a range of future scenarios (Ju et al., 2007). These estimates exclude the likely substantial greenhouse gas emissions from melting permafrost (Jin et al., 2000, Wang et al., 2006).

Water resources

The south of China has an abundance of water resources, and is unlikely to become stressed as a result of climate change, though the risk of flooding from increased heavy precipitation will likely increase (Lin and Zou, 2006), and saltwater intrusion into ground water and inundation of wetlands will likely be observed in this area (IPCC, 2007). Northwest China, however, is reliant upon water provision from the aforementioned vulnerable mountain ecosystems (Kang et al., 2007); the river basins of this region are the main source of water for consumption and irrigation, and the water flow in these rivers is largely determined by precipitation and snowmelt of permafrost areas (Wang et al., 2007).

A number of studies have used regional models to predict the impact of climate change upon water resources in China, and increased precipitation has been proven to be the main determinant of water flow in the river basins (Lan et al., 2006; Xu et al., 2003; Wang et al., 2007, Guo et al., 2002). Although most models predict an overall increase in precipitation (Xu et al., 2006a), it is noted that there is significant variation between regions (some decreases projected in areas of north, north east China (IPCC, 2007)). It must again be emphasized that modelling of precipitation and monsoon patterns is not of high confidence (Xu et al., 2006a), and therefore the model results must be treated with some degree of caution. However, all models are in agreement that the rise in precipitation in the north of China is not likely to compensate for the increase in evaporation that will result from increased temperatures at the levels projected (Huang et al., undated; Lin et al., 2007), and it is very likely that this will lead to a decrease in water availability in the northern regions (Lan et al., 2006). Similarly, the likely increase in summer droughts will reduce ice accumulation periods of permafrost regions (Lin et al., 2007; Lu et al., 2005).

Hydrological models have suggested that run off to rivers would be reduced under GCM climate

projections (Lan et al., 2006; Xu et al., 2003; Wang et al., 2007). The majority of hydrological models project a decrease in water supply in northern rivers due to subsequent reduced streamflow (Wang et al., 2007). A hydrological model driven by a range of SRES has calculated that deficiency would increase by 2% in the north and 3% in the northwest by 2050, rising to 4% in the northwest by 2080 (Lin and Zou, 2006). Similarly, used a range of GCM model outputs have been used to estimate the possible impacts of climate change on water supply in 14 major Chinese river basins (Kirschen et al., 2005). Whilst the model projections of water yields for each basin were highly regional, the study suggested that meeting the present demand of water supply in 2055 would require an increase in expenditure on water resources from $200 million to $700 million under one model, and would not be possible under others, with significant decreases in the Yangtze and Yellow River basins. This is consistent with BIOME models that show a significant decline in wetlands by 2100 (Ni et al., 2000).

Limited data on current stream-flow has been identified as one cause of uncertainty in the modelling process (Wang et al., 2007). Regional variation in results should be noted, with a number of studies projecting increased flow in the Xinjiang River (Kirschen et al., 2005; Shi et al., 2007). Different climatic changes may also be projected even within one hydrological region (Guo et al., 2002). Gao et al. (2003) suggest that along the Tianshan Mountains, precipitation is likely to decrease in a single area but increase in all other areas, and such variation has been noted in a number of different models (see Annex 10; Xu et al., 2006b).

Ecological impacts of reduced water resources

Most of the studies reviewed focus on modelling hydrological dynamics and river flow, without discussing the impacts that this will have on the surrounding natural ecosystems. Agricultural systems are more often considered. There has been little focus on the impacts upon ecosystem services overall. The likely increase in water stress for rain fed croplands should be noted, and the agricultural impacts of climate change are discussed below. There is little analysis and discussion of the impacts of changes to water cycles; there is little information on the potential impact on groundwater quality, recharge, and flow (Tao et al., 2003). Although there has been some modelling of vegetation distribution on the QTP using BIOME models (Ni et al., 2000) and Holdridge life zone classifications (Chen et al., 2003), these have not been combined with water resource studies. Water provisioning services of ecosystems such as grasslands are often not taken into account, nor the feedbacks that will occur from desertification, although an initial water balance model including soil holding capacity has shown this to have a large influence (Tao et al., 2005). Few models have included vegetation patterns and underlying surfaces around river basins (influencing both evaporation and run off) in hydrological models, and whilst a review of available models suggests a reduction in water resources for the Yellow River (Lan et al., 2006), it was noted that the impacts could vary widely across the region according to land use patterns. Indeed, the simulated streamflow for one model increased with increased grassland area and a reduced forest area (Chen et al., 2006). This highlights the importance of terrestrial ecosystems in water-provisioning services, and suggests a need for more thorough analyses with land use patterns incorporated, as well as feedbacks between changes in vegetation due to climate change and the climate models themselves (Kang et al., 2006).

Crop production

Various global scale studies have estimated the impact of climate change on crop yield in China. Rosenzweig and Parry (1994) found a small increase of 0 to +10% in national grain yield (defined as wheat, rice, coarse grains and protein feed) in China for two out of three climate models simulating a 2 x CO2 climate. When farm-level adaptation to climate change was assumed - through changes in planting date, irrigation and fertiliser practices - then all three climate models produced an increase in national grain yield. Changes of a similar magnitude were estimated by Arnell et al. (2001) using an unmitigated 1S92a scenario for 2080. In contrast, the global study of Parry et al. (2004) found a decrease in crop yield of -2.5 to -5% in 2020, rising to -5 to -10% by 2080 averaged across emission scenarios on the yield of wheat, maize, rice and soya combined. Therefore, the magnitude of yield change due to climate change appears to be small for China in these assessments, in general within ± 10% of the present day

Climate change may also shift areas suitable for crop cultivation. Wang (2002) concluded that areas of China where three crops per year can potentially be grown could extend 500 km northwards by 2100, shifting the double-cropping areas north, and reducing the single crop season area by 23%. Other studies are less clear. Thomas (2007) projected only a minor northwards shift of crop areas by 2030,

but instead found an expansion of the subtropical cropping zone. No general increase in land suitability for cereal production under climate change was found in the study of Fischer et al. (2005).

Most country-level assessments in China have studied the three staple crops; wheat, maize and rice. Matthews et al. (1997) used two rice crop simulation models and three GCMs with a 2 x CO2 scenario, and divided China into four agroecological zones (AEZ). The mean change in rice yield averaged over the three climate models was -4.2% and -8.4% for the two crop models, with a range of responses (from -30 to +6%) projected. Adaptation of rice production simulated through the use of temperature tolerant varieties, and a second rice crop per year where this became possible, changed the direction of the crop impact. Results ranged from a small positive yield response (for a change to a better adapted variety) to a large positive change (for inclusion of a second season crop).

Erda et al. (2005) also found large regional differences in the response of rice yields to climate change. On average, rice yield increased by up to 8% by 2080 under an A2 emission scenario, but decreased by 5% with a B2 scenario, with the magnitude of a change depending on whether the crop was irrigated or rainfed. Yield of maize crops increased under rainfed conditions, but decreased under irrigation for both scenarios (Table B5.1).

TableB5.1 Projected changes (%) in crop yield in China for 2050 under two emission scenarios compared to present (adapted from Erda et al., 2005)

	A2 scenario		*B2 scenario*	
	Rainfed	***irrigated***	***rainfed***	***irrigated***
Rice	3.4	6.2	-0.9	-1.2
Maize	18.4	-2.2	8.5	-1.3
Wheat	20.0	25.1	6.6	14.2

Winter wheat yields were projected to increase in three locations of China under two emission scenarios for 2071-2080 (Zhan et al., 2005). A similar positive response of wheat yields was found in the Changwu region (Zhang and Liu, 2005); three emission scenarios provided changes of 7, 10 and 9% for the year 2080. In the Huang-Hai Plain of northeast China, Thomson et al. (2006) found a yield increase of 0.8t ha-1 for the 2070-2099 period, using output from the same climate model as Zhang and Liu (2005), but with a different crop model. They accounted for this yield increase as the effects of warmer nights and increased precipitation.

B6 – Impact of invasive alien species (IAS) on ecosystem services and poverty alleviation

IAS status in China

The spread of IAS is now recognised as one of the greatest threats to the ecological and economic well-being of the planet. The total economic losses caused by IAS to China were estimated to be USD 14.45 billion, accounting for approximately 1.36% of China's GDP in 2000 (Xu et al., 2006). Fifty percent of invasive alien plants in China were intentionally introduced as pasture, animal feed, ornamental plants, fibre crops, medicinal plants, vegetables, or lawn plants; and 25% of alien animals were intentionally introduced for cultivation, husbandry, biological control or as pets (Xu et al., 2006). Between December 2001 and October 2003, a nationwide IAS survey[4] recorded 283 IAS across the country, including 19 microorganisms, 18 aquatic plants, 170 terrestrial plants, 25 aquatic invertebrates, 33 terrestrial invertebrates, 3 amphibians and reptiles, 10 fish and 5 mammals (Xu et al., 2004 and 2006). According to Xu et al (2006), these IAS were mainly distributed in farmlands (59.1%), forest (13.7%), marine (12.5) and wetland (7.2%).

China's rapid economic development, including the explosive growth in trade and transportation systems, is increasing the pathways for the introduction and spread of IAS between regions within China and from outside China. IAS information analysis shows that the species introduction rate of 1

[4] This survey was only focused on IAS in China introduced from other countries.

species per 8-10 years, recorded before 1990s, increased to 1-2 species per year after 1990s (Wan et al., 2005).

Impacts of IAS on ecosystem services

The introduction of IAS has been recognized as the second major cause of global biodiversity loss after direct habitat destruction (Sala et al., 2000). IAS affect both ecosystem structure and function (McNeely and Schutyser, 2003). It can transform the structure of ecosystems by repressing or excluding native species, either directly by out-competing them for resources or indirectly by changing the ecosystem processes (Li and Xie, 2002; Wan et al., 2005). In China, the introduction of IAS is one of the major causes of species extinction in freshwater ecosystems (Xie et al., 2001). IAS also affects ecosystem processes such as alteration of soil erosion rates and other geomorphological processes, biogeochemical cycles, hydrological cycles, nutrient cycles and fire regimes (Macdonald et al., 1989; Wan et al., 2005; Callaway and Maron, 2006). For example, Ageratina adenophora, an introduced weed, exhausts arable soil fertility due to its strong absorption of soil nutrients (Liu et al., 1989; Wan et al., 2005) and inhibits seed germination of neighboring plant species by releasing allelopathic substances into the soil (Wan et al., 2005; Zheng and Feng, 2005).

IAS also pose direct threats on sustainable agriculture and forestry production. They cause the direct damage to agricultural crops and forestry plants and indirectly affect the environment due to the spraying of broad-spectrum pesticides against invasive pests and weeds. For example, the rice water weevil from North America, Lissorhoptrus oryzophilus, was first reported in Hebei Province in 1988, and has now spread to 10 provinces. The area of infestation has doubled between 1996 and 2001. The weevil causes rice yield losses of 10-25% in average, and up to 50-70% or even no harvest in serious cases. It was estimated that extra 90t of pesticide were applied annually in rice fields of Zhejiang and Fujian provinces due to this biological invasion (Wan et al., 2005).

Impacts of IAS on poverty reduction

IAS can have a strong impact on land transformations, land degradation and affect traditional livelihoods as well as cultural and spiritual well-being, particularly for the poor rural communities dependent on nature's services for livelihoods and to fulfil basic needs for food, fibre and water (Ash and Jenkins, 2007). In China, no research has been conducted so far on the effects of IAS on poverty reduction. However, some studies in China have been redirected from pure control of IAS to integrated use of invasive plants to provide fiber, herbal medicines, botanical pesticides and biofuels, e.g. Ageratina adenophora, Micania micrantha (Wan et al., 2005). This might lead to a new dimension of integrating IAS control programme with rural livelihoods development in China through value added exploitation of IAS. However, the trade-off between such kinds of benefits by integrated use of IAS and their costs to biodiversity and ecosystems must be carefully and thoroughly assessed.

In our situation analysis, regional distribution of 279 IAS across China was compiled and overlaid with poverty counties in China (Figure B6.1). There appears to be positive correlation between economic development and the number of IAS species (Sax, 2002; Zhang et al. 2006). Except for the favorable climatic conditions in subtropics of China such as in the under-developed Yunnan Province and Guangxi Zhuang Autonomous Region, more IAS invade the economically developed east and southeast coastal provinces of China. This pattern of greater introductions of IAS in economically developed provinces with high GDP and human populations reflects how increased human economic development activities and/ or more suitable habitats might act as sources to further contribute to the dispersal of IAS to other under-developed provinces in the future.

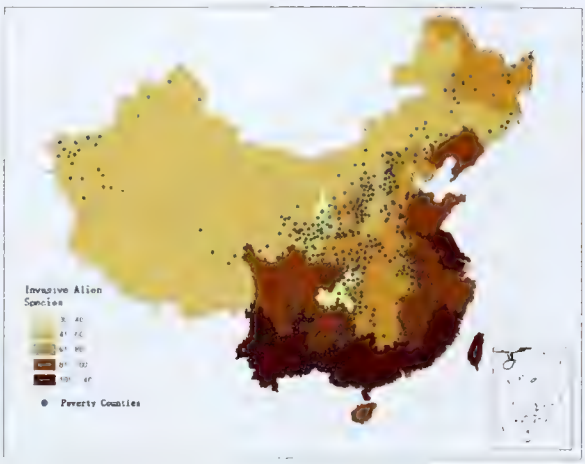


Figure B6.1 Spatial distribution of the 279 major IAS in China, overlaying with map of poverty counties. The species richness of IAS in every provincial administrative unit was collected according to the distribution records (Li and Xie, 2002; Xu and Qiang, 2004; Wan et al., 2005). The color codes represent the number of species in each province/region and municipal city.

Box-Key Messages

China faces a huge challenge of IAS with its rapid economic development, increasing global trade and transportation system. While the negative impacts of IAS on ecosystem structure and function are undisputed, understanding their potential impacts on rural livelihoods and well-being of the poor is less evident.

IAS management is one of the key measures to achieve beneficial circulation of ecosystems in western China (MAWEC, 2005) to support poverty alleviation. Compared with other under-developed poor regions, poor populations in Yunnan Province, Guangxi Zhuang Autonomours Region, Sichuan Province, Jiangxi Province and An'Hui Province experience relatively higher IAS introductions and may face greater challenges posed by IAS (Figure B6.1).

B7 – Role of science and technology in ecosystem management for poverty reduction

China's science and technology (S&T) undertakings have experienced rapid development in the past few decades. China government's expenditure for S&T in 2006 was RMB 1688.5 million yuan, a twelve-fold increase since 1990. The average government expenditure for S&T accounts for 4.24% of total government expenditures, an increase from 3.6% in 2000.

Science and technology in agricultural growth

During the past decades agricultural S&T has played an important role in the growth of China's agriculture and productivity improvement, which has in turn increased farmers' income, reduced poverty, improved food security and society stabilization.

The green revolution emerging in Asia in the 1960s produced prolific varieties selected and bred by agricultural research centers that promoted remarkable agricultural production in many countries. Rapid growth of agriculture impelled the economic boom of these countries and regions in the 1980s and 1990s.

China began to implement its rural household responsibility system and market system reform in 1979, and at the same time the amount of investment in agricultural research increased rapidly. These measures promoted agriculture production in China. Prior to the reform (from 1952 to 1977) China's

agriculture GDP grew at about 3.66% per year, and accelerated to more than 4% after the reform (from 1978 to now), which exceeds that of most countries. Some research shows that before 1979 about 95% of agricultural GDP growth can be attributed to input increase, and only 5% can be attributed to productivity growth. Since 1979, productivity growth contributes most of the agricultural GDP growth, and its share of contribution is about 71%. S&T is one source of productivity growth. For example, the combined contribution of fertilizer and machinery to the growth of farm production in northwest China during 1978–1998 was about 45% (Deng et al., 2004). Additionally, genetically modified crops have increased yield and quality. Furthermore, with the maturation of China's market mechanism, the effects of institutional innovation to agriculture growth are limited; arable land and agricultural labor are scarcer. Thus, agriculture growth will further depend on the advancement of agricultural technology.

Science and technology in poverty reduction

Public investment in agricultural S&T investment has had a significant effect in alleviating poverty in China, particularly in less-developed or poorly-endowed regions. Some experts estimated that one additional unit of input in agricultural research and development (R&D) can result in an increase of nearly 10 units of agricultural output; every RMB 10,000 yuan of investment in agricultural R&D can help 7 people move out of poverty at the national level, while the same amount of money can help more than 30 people move out of poverty in western China, where the majority of the poor are found. Studies by the Institute of Agricultural Economy and Development of CAAS have shown that for every RMB 1 yuan invested in education, road, communication, irrigation, electric power or S&T, the increase in agricultural GDP is RMB 3.71, 2.12, 1.91, 1.88, 0.54 and 9.59 yuan, respectively. Similarly, for every RMB 1 yuan investied in these fields, the income increase in crop productivity is RMB 2.02, 1.95, 1.84, 5.56, 1.37 and 4.41yuan, respectively. Thus, farmers could get a high return from S&T investment. Some studies indicate that the average return rate of agricultural S&T investment in developing countries is 40%-60%, in China it is 50%.

There are many channels through which agricultural S&T could impact poverty alleviation. First, agricultural S&T improves agricultural productivity, and thus, it can directly increase farmers' income and help to create more employment opportunities in both rural and urban areas for the poor; Second, agricultural S&T increases agricultural production and thus lowers the food price, allowing the absolute poor people to buy more food at lower price and live better. Poor people, especially absolute poor people, whose major expenditures are food, can buy more agricultural products at lower prices, lifting them out of poverty and hunger; Third, high and new technology, such as bio-technology and information technology, has impelled the transfer from traditional agriculture to modern agriculture and improved the farm product competition.

In China, the contribution ratio of agricultural S&T is 48%, lower than developed countries. The reasons for low contribution ratio are: one is that the research and innovation capacity of the agricultural sector is not strong; the other is low transfer ration of S&T outcomes and S&T is separated from the economy.

Rural energy technology in the form of micro-hydropower, biogas, solar, and energy efficient stoves has contributed to reduced fuel wood use and more sustainable forestry management (Zheng, 2003). Hybrid rice technology invented by Yuan Longping has been adopted by more than 30 countries and regions, planting area are about 1.5 million hectares, the increased crop production provides enough food for 70 million people. In fact, technology is being deployed by the Chinese government to combat a series of ecosystem challenges such as desertification (CCICCD, 1996) and drought, which are directly associated with poverty conditions.

Science and technology also affect ecosystem and poverty reduction indirectly via its influence on national policies and the decision-making process. Policymakers are known to consider scientific findings when developing policies. For example, advances in climate change science have raised awareness of China's contribution to global warming. In response, China's 11th 5-Year plan is targeting a 20% cut in energy consumption per unit GDP from 2005 to 2010. S&T can also indirectly induce policy change. For example, to encourage adoption of new technologies and increase investments in agriculture, a new policy was developed to extend land tenure to 30 years for farm households. The contribution of this policy change accounted for 21% productivity growth during this period.

Section C: Challenges and research needs for ecosystem services and management for poverty reduction in China

This section highlights the key challenges and research needs for ecosystem services and management to alleviate poverty in China. These findings are drawn from the situation analysis, the Ningxia case study, and consultations with the Advisory Committee, but should not be considered as exhaustive due to the relatively short time frame of this study. In proposing a research strategy, the overall aim is to increase shared and wide-scale understanding of the linkages between ecosystems and services important to the poor, and the drivers of change that impact on these, so that China can sustainably manage its ecosystems to alleviate poverty and provide for the future generations to come.

C1 – Challenges

We identify the following five key challenges to ecosystem services and management for poverty reduction in China, which are anchored from different aspects of status quo, enabling environment, implementation level, management mechanism and information and knowledge support, respectively:

- ***Significant number of poor populations and extensive fragile ecosystem.*** Currently, China is entering a new phase of poverty alleviation, with major challenges such as the still huge numbers of remaining poor and high risks of those just out of poverty falling back into poverty. Most of the remaining poor live in fragile ecosystem areas, such as grasslands, mountain areas, desert areas, and the loess plateau. These areas often have a high prevalence of endemic diseases. Development infrastructure is limited, productive capacity is low and investment costs to improve conditions are high. The literacy levels of the remaining poor are also very low, with only primary school education or less. In addition, China faces the complex challenge of feeding its large population, and eradicating its significant remaining poverty, whilst trying to assure an equitable, efficient and sustainable use of its limited natural resources, protect its environment and adapt to climate change.

- ***Increasing impact of global change on fragile ecosystems and the poor reliant on ecosystem services.*** Most of the remaining rural poor of China live in the extensive grassland and mountain environments which are of low productivity and are ecologically fragile. These regions are also the source of the country's major rivers and the parts of the country most likely to be most impacted by climate change. The poor in these regions will be affected by increasing climate variability and frequency of natural disasters such as drought, snow storms and floods. The poor can also not meet the investment to increase the resilience of their production against the effects of climate change, e.g. construction of irrigation systems in drought areas. Additionally, as massive flows of people and goods come into China this opens up many pathways for entry of invasive alien species, which can become major challenges to healthy ecosystems and poverty alleviation.

- ***Lack of effective multi-disciplinary and multi-stakeholder engagement (national and international).*** Due to the multi-disciplinary nature of managing ecosystems and their services for poverty reduction, cooperation is required between different research communities, government sectors, NGOs and rural communities, but in China mechanisms and capacities to analyse this complex challenge and implement new approaches are scarce. China requires integrated and sustainable plans for poverty alleviation through active multi-stakeholder participation. This also includes the involvement of international expertise and opportunities to learn from other regions. The cooperation between and coordination of national/bodies/actors are presently weak, e.g. lack of ability to form synergistic alliances and work together to tackle the complex problems concerning both the economy and environment in a win-win manner. Rapid economic growth and intensive development at both the local and national scales are also contributing to this challenge through the increase in demand for ecosystem services and the exacerbation of pollution problems.

- ***Absence of integrated and whole-system perspective management for ecosystem services and poverty alleviation.*** All of the ecosystem services in China are either in decline, or increasing at a rate slower than demand. This is in part because relevant policies in the environment and poverty reduction sectors often focus on improving one ecosystem service, such as food production or reduction of soil erosion, with inadequate consideration of the inter-relationships with other

ecosystem services. Attention on the supporting services or ecosystem processes such as soil formation and water cycling, is needed to improve the effectiveness and sustainability of management for the provisioning, regulating and cultural ecosystem services. The inter-relationships between these services need to be better understood, and policy-makers and project implementing agencies should apply this in their decision making. Similarly, research and actions for ecosystem management and poverty reduction need to view these issues with a holistic perspective, as a whole social and ecological system, recognising that people are part of the ecosystem.

- ***Information and knowledge gaps.*** Throughout the situation analysis we consistently found gaps in information and knowledge (particularly for methods and management tools), as a major challenge to research and ecosystem management for poverty alleviation in China. Information/data gaps are listed in Annex 12. Data sharing mechanisms in China are not well established and high quality international data are not fully utilized in research due to technology, language and knowledge issues. There is a strong need for education and training in ecosystem management and poverty alleviation at national, institutional, regional, local and individual levels. There is also a high demand for an innovative top-down and bottom-up interactive information systems and services to be established.

C2 – Research needs for ecosystem services and poverty alleviation in China

Based on the major challenges and research gaps identified, the principal research needs are:

1. Poverty in China

China has been successful in reducing poverty in the past two decades, but it has become increasingly difficult to reach the remaining poor. This study found a lack of available information on who and where are the poor in China, and little analysis of the causes of poverty in specific localities, although such information may well exist. Priority research needs to further strengthen China's rural poverty reduction programmes include:

1.1 Develop a conceptual framework of human well-being and ecological systems and measurement methods for understanding these relationships to promote poverty reduction, taking a holistic and social-ecological systems approach.

1.2 Identify and analyse the localities and causes of poverty in the different ecological zones in China, including consideration of the different ecosystem properties of productivity, risk of transformation to a degraded state, and response when rested of simplifying or diversifying ecosystem processes.

1.3 Assess the relative importance of degradation of ecosystem services in making the poor, and rural communities in general, more vulnerable to natural disasters, as well as worsening the scale of disasters.

1.4 Examine the potential for increasing the resilience of the poor in China to natural disasters by improving the flows of different ecosystem services, considering the different ecological regions.

1.5 Develop methods and gather information to understand which ecosystem services are most important to the poor in China in terms of the conceptual framework above in different ecological areas.

1.6 Assess how policies of community ownership in China impact on the supply of ecosystem services and poverty, especially in grasslands.

1.7 Analyse current poverty reduction policies and mechanisms in China to identify opportunities and needs to further strengthen their impact through improved management of ecosystem services.

2. Ecosystems in China

Ecosystems in China have undergone tremendous change as the country develops and in many places they are over-exploited and degraded. To overcome the negative impacts of ecosystem change as identified in Section A2, further research is needed on the following:

2.1 Determine the potential biophysical capacity for supply of ecosystem services at the provincial and county scale in areas with poverty under current land use, e.g. cropland, forest, and grassland, and under possible scenarios of land use change.

2.2 Examine effects of ecosystem fragmentation on ecosystem functions and supply of services, including impacts on biodiversity and ecosystems in a natural state and poverty processes. For example, there are over 85,000 reservoirs in China, but the downstream effects of these on ecosystem services, poverty and their relationship have not been assessed.

2.3 Conduct integrated analysis (ecological-social-economic systems) and investigate ecosystem dynamics and strategies for better ecosystem management and poverty reduction, particularly to improve farmland productivity and value, restoration of wetlands, and management of ecologically fragile areas such as the Qinghai-Tibetan Plateau.

3. Supply of ecosystem services

As ecosystems become degraded ecological processes and functioning are affected, leading to changes in the supply of ecosystem services. For example, land use change and degradation resulting in shortages of water provisioning and regulating ecosystem services are one of the most widespread problems in China. In other instances, the basis of ecological processes and functioning is not well understood. A clear example is the poor understanding of the role of biodiversity in ecosystem functioning and supply of services. Based on the analysis in Sections A3 and A4, further research is needed on the following:

3.1 Analysis is required of the trade-offs in time and space between the supply of ecosystem services important to the poor, e.g. what are the most limiting ecosystem processes and properties in each region, such as the water cycle, soil properties, or biomass production and nutrient cycling.

3.2 Conduct integrated applied research on ways out of the groundwater crisis in parts of northern China, with particular focus on the effects of agriculture, afforestation and grassland management on the water cycle in the ecosystem, food security needs and developing pro-poor governance mechanisms. This should be linked with analysis of potential climate change impacts.

3.3 Examine the effects of ecosystem use in upper watersheds and the functioning of ecosystem services downstream, particularly for water supply for all rivers and for floods in the Huai River. Understanding the hydrological impact of afforestation is particularly important.

3.4 Studies to develop drought-resistant and 'disaster-resistant' agriculture, focused on poverty areas in semi-arid regions, e.g. improved soil properties for water infiltration and minimising evaporation, crop-resistance to drying winds, hail storms, frost, sand storms in north and west China.

3.5 Determine the thresholds of transformation of the ecosystems such that there are no major reductions in the supply of valuable ecosystem services. For example, for a tree plantation, what are the minimum structural requirements and biodiversity components for it to provide necessary erosion control?

3.6 Research ways of increasing the variety of agriculture crops and biodiversity in production systems (which currently rely heavily on only a few major crops) to improve ecosystem processes and services, including resilience to natural disasters.

3.7 The following research is crucial to better address grassland degradation in China, which is very extensive and a major cause of poverty, sand storms and disruption of downstream water regulation:

- determine the socio-economic drivers of grassland degradation and recovery, including land tenure, population density, and government policies.
- develop the theory, research methods and data to assess the intrinsic ecosystem properties of grasslands, such as response to being rested from disturbance (simplifying or diversifying of ecosystem processes), risk and thresholds of transformation to a degraded state, and biophysical productivity potential. Evidence for change should include time periods of at least twenty years.
- review the suitability of theories such as grassland management by livestock carrying capacity and fencing in northern China, where very high variability in rainfall between years and spatially results in great variability in grass production,
- identify the most vulnerable sites in which provisioning and regulating capacity of grasslands ecosystems are reduced or at risk, including areas outside the poverty counties.

3.8 Develop research methods and decision-support for management of different ecosystems in a locality or region as inter-related aspects of one larger ecosystem. An example is the flow of water and minerals between grasslands and forests and rivers and wetlands.

3.9 Investigations to improve methods for agricultural zoning to adapt to local ecosystem conditions and the needs to have multiple ecosystem services (such as food or timber production, soil erosion control and groundwater recharging and cultural services) with inclusion of participation of local people and focusing on poverty reduction.

3.10 Studies to develop and promote more productive and sustainable agriculture on existing agricultural lands where cropping areas are reduced by logging bans and the Sloping Lands Conversion Programme.

3.11 The following research is important for those whose livelihood is dependent on the land to take advantage of the opportunities presented by sound management of ecosystems for carbon sequestration:

- Assess the potential for increasing organic soil carbon stocks in China through management of croplands, grasslands and forestry.
- Determine better estimates of the soil organic carbon stocks and effects of scale in soil carbon mapping to converge towards more dependable and consistent estimates of carbon sequestration potential.
- Conduct an assessment of regions for their role as carbon source/sinks to determine ways that they can be managed to enhance carbon sequestration.

4. Underlying drivers of ecosystem change and poverty

The ESPA work analyses have identified population growth, economic development, migration, trade, governance, land tenure and public participation and environmental awareness to have great impact on ecosystems and poverty in China. For example, in many regions the population density has exceeded the productive capacity of local ecosystems, many of which are now degraded. Based on these findings of indirect drivers' impacts on ecosystem change and poverty in section B1 of this report, the following research priorities are proposed:

4.1 Assess the impact of increasing free trade and industrialised production of ecosystem provisioning services (such as timber, grain, cash crops, livestock products) on ecosystem services and poverty in China.

4.2 Determine the current and potential biophysical capacity of specific ecosystems to supply services, and to correlate this with sustainable population levels and livelihoods, focusing on poverty reduction. This information is needed to guide land use planning and projects for 'ecological migration' of people from degraded areas to more productive lands, which on the one hand seek to reduce the local population pressure and improve ecosystem condition in the migration source region, and on the other hand reduce poverty through relocation of the population and more rational utilization of land resources.

4.3 Economic growth in China has been a major factor in reducing poverty in rural areas, but the relationship at a local scale between economic growth and ecosystem services and poverty reduction needs to better understood. For example, in Ningxia, industrial parks are established through diverting water from the Yellow River to new mining and agriculture areas near a drought-stricken poverty region, to employ rural labor in industry and service sectors, but the effects of industrialization and increased employment on local poverty alleviation and ecosystem restoration need to be better understood.

4.4 Tourism around some nature reserves has significantly increased local communities' income. A research need is to further understand the relationships between improved or conserved ecosystems, tourism development, poverty reduction, and to study the economic mechanism supporting this phenomenon.

4.5 Energy sources in many rural areas are changing in response to government programmes and increased income levels, such as introducing biogas, wind and solar power, and coal for grassland areas or natural gas for agricultural areas. Research is needed on the impacts of these changes on ecosystem functions and services, such as reduced use of firewood and animal dung. The policy logic is to introduce new types of energy into rural areas, to diminish energy exploitation pressure on the local ecosystem and reduce poverty.

5. Major policies and programmes affecting ecosystems in China

China has formulated many separate policies and programmes for ecosystem management and poverty alleviation. However, these lack linkages and incentive mechanisms to integrate them. Based on the analysis of the major policies and programmes in section B2 of this report, the following research priorities are proposed:

5.1 Evaluate the impact on all categories of ecosystem services of policies and programmes for poverty alleviation and natural resource management (land use; management of water, grassland and forests; protected areas; pollution control), particularly the National Plan for Ecological Construction and the 11th Five-Year Plan.

5.2 Design systems to identify and promote ecosystem services important to the poor in poverty alleviation policies and programmes during their formulation, monitoring and evaluation.

5.3 Research incentive mechanisms to encourage public participation in the design, implementation and monitoring of policies and programmes affecting ecosystem services and poverty alleviation.

5.4 Identify the constraints and successes in making multi-sectoral policy design and implementation in China, to promote adaptive management practices such as monitoring and testing of assumptions.

6. Valuation of ecosystem services

Though extensive valuation studies have done in China and many actual eco-compensation schemes, including Payments for Environmental Service (PES), are being implemented, the two are rarely linked. Studies are needed to enable better valuation of ecosystem services that can then be translated into eco-compensation schemes. Below are the research needs identified based on the findings in section B3.

6.1 Develop practical eco-compensation standards and guidelines across the diverse ecosystems and situations of China, including non-economic and economic values. A compilation of existing methods used at local, regional, and national levels, assessment of implementation challenges, and identification of gaps is needed that would then guide focused research on particular ecosystems (especially concerning forests, grasslands, and wetlands). This work would need to be complemented by parallel institutional and policy analyses identifying institutional constraints as well as appropriate legal frameworks.

6.2 Better understand flows of ecosystem services in terms of suppliers and beneficiaries, to support the identification of possible buyers and sellers of services. Producing spatially explicit maps of regional ecosystem service flows for the existing priority forestry programs would be helpful. Multi-scale assessments focusing on the intermediate scale can feed into implementation of key State Forest Development programs. Ningxia may provide a good example at the smaller scale since local watershed eco-compensation schemes are being developed.

6.3 Evaluate trade-offs among multiple ecosystem services to inform resource management decision-making, particularly among hydrological services, traditional commodity production such as agriculture and timber, and urban development in China. For example, integrated river basin management planning and environmental impact assessment are in need of trade-off analyses to assess conservation and development alternatives.

6.4 Develop practical monitoring systems for on-going tracking of ecosystem service supplies to set baselines and inform eco-compensation schemes. The key State Forest Programs, including the Sloping Lands Conversion Program and National Forest Protection Program, as well as the Forest Ecosystem Compensation Fund are important targets that can be tested at multiple scales for monitoring of ecosystem service provisioning.

6.5 Understand how to better target PES for poverty reduction, and ensure that PES will at least not worsen poverty. In targeted poverty areas, analyze relationships between ecosystem service provisioning for PES and multiple aspects of well-being for humans, identifying key indicators of human well-being that are most relevant to ecosystem service provisioning here in China. These outputs can help refine maps that overlay socio-economic factors with ecosystem service supply and consumption to better understand beneficiaries and potential impacts on the poor.

6.6 Better understand how the poor value ecosystem services, including non-market values, and what incentives might best influence their resource management activities. Targeted areas for social

science research would best be conducted in overlapping areas with natural science work, thus providing good testing grounds for multi-scale, interdisciplinary, social and natural science research efforts.

7. *Pollution impacts on ecosystems and poverty*

There is a lack of sound analysis and understanding of the effects of pollution and over-use on ecosystem services and the extent to which these impact poor ecosystem users. There are also gaps in understanding the flows and transformations of pollutants in agricultural ecosystems under conventional or enhanced management. Agricultural research does not usually consider if technologies are acceptable to farmers in economic and socio-cultural terms. Therefore, such research should include or start from finding out more about the situation, needs and traditional management of the target groups in poverty areas.

7.1 Intensification of agriculture and livestock production often causes pesticide and nutrient pollution of ground water and wetlands and impairment of human health. Research is needed to describe the situation in more detail at the scale of a poverty county for guidance of agricultural policies. Such research should have a strong farmer focus. Successful projects have focused on integrated crop management, for example in greenhouses of Hebei (MOA-GTZ cooperation) to save resources (water, agrochemicals), protect water and soils, and improve farmers' income through upgraded extension services. Participatory work with farmers to promote sustainable agricultural practice and adaptation to climate change will be initiated by MOA-FAO in the Yellow River Basin on a regional scale. To preserve environmental water, reduction of phosphorus loads is crucial, as is the reduction of nitrate loads with regard to drinking water. Cooperation with UK advanced research organisations (e.g. Centre for Sustainable Water Management, Lancaster or Centre for Water Science, Cranfield, etc.) would be desirable, also for better guidance on agricultural policies.

7.2 Identify the dominant drivers of agricultural pollution and over-exploitation with regard to potential for reduction, reuse and recycling of resources in agriculture. This research topic alludes to the fact that agriculture is both a recipient of pollutants as well as an emitter. While water resources are getting scarcer, especially in the north, better management of municipal wastewater and residues from intensive animal production in agriculture are priority issues. Research results of enhanced technologies, e.g. conservation tillage and buffer strips, residue and carbon management, demand-oriented fertilization, integrated pest management, water-saving irrigation practices, derived under field conditions can be valuated and up-scaled to support incentive mechanisms. Priority areas are agricultural ecosystems in North China, e.g. Yellow River Basin.

8. *Potential impacts of climate change on ecosystem services*

Climate change is expected to be a major driver of change in natural and managed ecosystems. There is a clear need for further research on the likely impacts of changes in temperature and precipitation on ecosystem services, as well as on the ecosystems themselves, and the implications for human livelihoods. No information was identified on impacts on soil formation, pollination, nutrient cycling, supply of freshwater fish and wild meats, fuelwood and timber, biochemicals and genetic resources, or cultural services. Similarly, there is a lack of information on impacts on wild species, despite the existence of suitable data for some taxa and a number of studies on the influence of climate variables on species richness in China.

Considerably more work has been undertaken on water and food resources. Food security for the poor includes issues of food production, supply and access that rely heavily on the interplay of a number of ecosystems functions in a complex but poorly understood way. Below are the research needs identified based on the findings in section B5.

8.1 Undertake basic research into the likely impacts of climate change on those ecosystem services other than food provision that are important to the livelihood of the poor.

8.2 Evaluate the impacts of climate change on food production and food security, including consideration of the links and flows of services between managed and natural ecosystems, especially for the water cycle within food provisioning systems. This should include systematic investigations of the implications of uncertainties of predictions.

8.3 There is some evidence that enhanced concentrations of ground-level ozone may offset the benefits to crop growth of elevated CO_2. If true, this will have negative consequences for those dependent on agriculture for their livelihood. The combined impacts of elevated CO_2 and ozone on agriculture should be determined for crops important to food systems of the poor.

8.4 The poorest communities are also those that are most vulnerable to the potential impacts of climate variability and change, in particularly natural climate disasters. Adaptation of farming practices to the year to year variability of climate is particularly difficult given the uncertain nature of extreme weather events. The development of strategies for the adaptation of managed and natural ecosystems to projected changes in frequency of extreme events such as drought, heat waves and flooding are badly needed.

8.5 Montane ecosystems are particularly fragile, but are home to a high proportion of the poor. Evaluation of the likely effects of climate change on montane hydrology, glacier melt and the timing and amount of water availability downstream is required.

8.6 Most studies to date have concentrated on the major stable crops of rice, wheat and maize. However, many other crops form the basis of the livelihoods of the poor. Therefore, the potential impacts of climate change on crops other than these three important staples, and including bioenergy and textile crops should be studied.

8.7 Further research also needs to consider adaptation strategies. It is essential that national climate change adaptation plans are informed by an ecosystems approach. Interdisciplinary work is urgently needed to support efforts to decrease the vulnerability to climate change of China's ecosystems and their dependent people. Impacts upon ecosystem services could potentially be both exacerbated and reduced by human activities such as ecosystem management. Projections of crop yield on seasonal to decadal timescales, using a range of adaptation options, will begin to clarify how adaptation planning can best manage risk. Increased integration of the natural and social sciences, with full awareness of associated uncertainties, is vital in order to assess social vulnerability to climate change.

9. Impacts of invasive alien species (IAS) on ecosystem services and poverty alleviation

China faces a huge challenge of IAS which can cause ecological disasters and economic losses in various ecosystems - croplands, forests, grasslands, islands, fishery, marine and natural conservation areas. IAS management is one of the key measures to achieve beneficial flows of ecosystem services in China to support poverty alleviation. To tackle the IAS problems with an ecologically-sound and sustainable approach, the following are the prioritized research needs identified in Section B6 and Annex 11.

9.1 Investigate invasion mechanisms and ecology-based management approaches (e.g. biological control, ecological restoration) for those IAS that seriously affect the poor in Yunnan Province, Guangxi Zhuang Autonomous Region and Sichuan Province, e.g. *Ageratina adenophora*, *Alternanthera philoxcroides* and *Eichhornia crassipes*, etc. Also, evaluate direct and indirect interactions of climate change with IAS at different stages of invasion, including pathway, establishment and dispersal.

9.2 Study and develop an effective IAS monitoring and diagnostic system incorporating elements of community-based surveillance in poor regions of western China to put into operation efficient early warning systems.

9.3 Examine aspects of human interactions with IAS that encourage successful invasion, to support risk assessment and decision-making on introduction of alien species for commercial exploitation and/or economic benefits, especially under the current focus on and interest in introducing biofuel plants.

9.4 Evaluate ecosystem responses to IAS, especially quantitative studies of IAS impact on the structure, function and services of ecosystems at multi-trophic levels and spatial-temporal scales.

9.5 Research the impact of IAS on the rural poor relying on ecosystem services in the poor regions of western China, and assess the trade-offs between integrated use of IAS by the poor and their costs to indigenous biodiversity and ecosystems.

C3 – Research priorities for ecosystem management for poverty reduction in China

From the above research needs we highly recommend the following cross-sectoral research priorities for financial investment in the first instance:

- ***Identification of the inherent characteristics and relationships between ecosystem services and***

poverty alleviation at the regional scale. This requires some sample areas for case studies to identify the linkages between poverty and the diverse ecosystems of China under an improved conceptual framework of human well-being and ecological systems. This includes investigating ecosystem functioning, dynamics and supplies of services under diverse management practices and social systems, including household level research. Policy applications for this research include improved knowledge for valuation of ecosystem services and integration of PES in ecosystem management and poverty alleviation. It should also identify the dominant barriers and drivers for managing ecosystems for multiple services and poverty alleviation. Therefore, four representative areas would be selected from the Yellow River Basin for area comparison and relationship research (i.e. poor ecosystem with higher income per capita, poor ecosystem with lower income per capita, good ecosystem with higher income per capita, and good ecosystem with lower income per capita). The case study would provide clues or primary evidence on the relationship between ecosystem service improvement and poverty alleviation.

- ***Understanding of how ecosystem functioning becomes degraded, particularly for shortages of water provisioning and regulating ecosystem services.*** This research priority includes analysis of the trade-offs in time and space between the supply of ecosystem services important to the poor, e.g. exploration of the most limiting ecosystem processes and properties for poverty reduction, such as the water cycle, soil properties, or biomass production and nutrient cycling. Ecosystem mapping and spatial modelling of ecosystem dynamics need to be conducted in regions with poverty and fragile ecosystems. This study will focus on grassland in North China, which has a high risk of ecosystem transformation to a degraded state, and is characterized by low precipitation and a shortage of water resources. Analysis should determine the status of ecosystem processes, services in relation to the state of alteration of the ecosystem from a natural state, and relate this to different forms of management. The research should include participatory collection and analysis of data.

- ***Exploration of effective soil and water management to support poverty reduction needs and productive ecosystems.*** Effective soil and water management are very important activities for agricultural production in degraded ecosystem areas and thus for poverty alleviation. This research priority is also in response to the gaps in understanding the flows and transformations of pollutants in agricultural ecosystems under conventional or enhanced management. Research is needed to integrate agricultural management with reduced pollution risks and ecosystem service degradation, and to describe the situation in more detail at the scale of a poverty county for guidance of agricultural policies. We recommend conducting such research in the Loess Plateau and North Plain regions which account for 57% of the modelled total crop production capabilities of China, to address the problems of low productivity largely caused by scarce vegetation cover, low precipitation, fragile ecosystems, and soil erosion. The findings could help improve the productivity and sustainability of agricultural ecosystems.

- ***Evaluation of the impacts of climate change on ecosystem services and regional adaptation of the practices of agricultural production to climate change.*** This research priority should address the impacts of climate change on food production and food security, including consideration of the links and flows of services between managed and natural ecosystems, focusing on the water cycle at different scales and within food systems. It requires further study on forecasting and monitoring the impacts of climate change, and development of strategies for the adaptation of managed and natural ecosystems to possible changes in natural climate disasters, such as the adaptation of agricultural practices to droughts. We suggest implementing pilot studies in the upper, middle and lower reaches of the Yellow River Basin, to assess vulnerabilities of the agricultural sector and the poor to climate change, and propose win-win or at least no-regret strategies.

- ***Evaluation of ecosystem response and resilience to invasive alien species, and the impact of invasion on native ecosystems and their associated ecosystem services.*** This research priority requires quantitative studies of IAS impact on the structure, function and services of ecosystems at multi-trophic levels and spatial-temporal scales. This should be also linked with interaction effects between invasive alien species and native species to further our understanding of invasion mechanisms, and thus develop ecology-based management approaches (e.g. biological control, ecological restoration) to control and manage those invasive species(e.g. *Ageratina adenophora*, *Alternanthera philoxcroides*, *Eichhornia crassipes*) that seriously affect the ecosystem and the

poor in western China. For better understanding of the ecosystem response to IAS, we recommend more research on major species such as *Ageratina adenophora* in southwest China. The research outputs will help to develop sustainable management approaches to tackle the weed problem thereby benefitting the poor living on grasslands with livestock production, particularly in Yunnan and Sichuan Provinces.

- ***Development of management mechanisms to incorporate ecosystem services into poverty alleviation strategies, promoting integrated and whole-system perspective management.*** This research priority includes exploration of incentive mechanisms to encourage public participation in the design and monitoring of policies and programmes affecting ecosystem services and poverty alleviation. A sound management mechanism should also take into consideration the biophysical potential of ecosystem provisioning services (e.g. productive capacity) in relation to population density, as well as socio-economic analysis of ecosystem degradation and recovery (e.g. grassland) under current Chinese government policies. One possible case study would be to analyze the mechanisms or institutional arrangements that exist for eco-compensation, such as 'ecological migration' and watershed protection in the Yellow River Basin.
- ***Exploration of an innovative knowledge and information extension system for the uptake and utilisation of ESPA research results.*** An innovative system is needed to nurture the demand for and application of ESPA-relevant knowledge and technologies, not just among primary research providers, but for policy makers, NGOs, product and service retailers, traders and processors, financial institutions, private companies and farmers. The approach should shift the focus of attention away from just the generation of new information and knowledge to the ways in which these can be readily accessed and put to productive use. Such systems would strongly support, sustain and underpin the multi-disciplinary collaboration mechanism among institutions of natural sciences and social sciences at different levels required to address ESPA issues in China. A pilot study can be conducted which would adopt participatory approaches and set up knowledge and information networks to build up cross-disciplinary understanding and communities of practices on ESPA.

Section D: Capacity development strategy for research providers and users to maximise sustainable ecosystem management for poverty alleviation in China.

This section first summarises the key knowledge gaps and skill needs identified through semi-structured questionnaires and interviews with key stakeholders and literature reviews. It then proposes a capacity development priority strategy for research providers and users in China. Research providers are defined as those who generate and make available knowledge on ecosystem and poverty alleviation, including research institutions and universities. Research users include research providers and policy makers, implementation/extension agencies, NGOs and farmers. To reach higher impact under local conditions, our proposed strategy considers China's major sustainable development strategy in the 11th Five Year Plan, China Poverty Reduction Strategy (2001-2010), China's Agenda 21, Western Development Strategy and the White Paper on China's Environmental Protection (1996-2005). Our approach is also developed according to a capacity development framework with knowledge network approach and mode of decision-making based on proper awareness, knowledge, understanding, goals, values, skills, tools, resources and social options (Annex 11), and as well as the conceptual framework and analytical approach of the MA.

D1 – Assessment of the knowledge and skills needs of researcher providers and users

Semi-structured questionnaires were designed and distributed to researchers and policy makers to assess their knowledge and skills needs for ecosystem management and poverty alleviation (Annex 13). In addition, face-to-face interviews with key stakeholders (Annex 16), especially policy makers, NGOs and farmers, and literature reviews were also conducted to complement the questionnaire survey.

Conceptual understanding of ecosystem management, poverty reduction and linkages

Most of the interviewees have a general understanding of ecosystems, but the understanding of poverty and environment linkages by interviewees at local and national levels was limited. Both government agencies and poor farmers lack incentives to improve ecosystem management. Many environmental NGOs and CBOs underestimate the importance of the Poverty Reduction Strategy to their work. The majority of researchers and policy-makers however believe that ecosystem management can benefit poverty alleviation efforts. The critical knowledge gaps that researchers and policy-makers face are large discrepancies in knowledge of staff involved in the ecosystem management and poverty reduction. Conceptual understanding of ecosystem management is also recognized by policy-makers as a critical knowledge gap. To reduce these knowledge gaps, training is identified as the most useful way by both interviewed researchers and policy makers.

Information availability and accessibility

For researchers and policy-makers the internet has become the predominant information source, instead of libraries and workshops/meetings. However, many researchers have not had sufficient information available to carry out relevant analyses on ecosystem management and poverty alleviation. Internal exchange between stakeholders either formally or informally is very sparse. Direct exchange of information between researchers/agencies/countries is also very limited. For policy-makers, technical guidelines, research findings, guidance notes and databases are mostly available to support decision-making of ecosystem management and poverty alleviation. Workshops are considered the most efficient way to collect information and know-how for decision-making. An extension system with efficient technology transfer is recognised by farmers as a very important means to improve agricultural productivity.

Expertise on ecosystem management

Of the interviewed researchers 78% believe that their teams have the technical capacity to analyse ecosystem management and poverty reduction. However, technical expertise on the linkage of these two areas is very much required by researchers and policy-makers. Further assistance for capacity building is very much appreciated by most of the interviewees. As for regional collaboration, funding is identified as the critical constraints to this activity. It seems that English language is not a problem

for researchers in their research activities, but the language skill is lacking in the lower level policy implementation agencies. Lack of money, infrastructure, technology and water irrigation/drinking system are the main barriers that prevent poor farmers reducing their vulnerability to natural disasters.

Key messages of knowledge gaps and skill needs identified from the assessment

- Awareness and understanding on the linkage of ecosystem services and poverty alleviation is sparse;
- Knowledge exchange and information sharing between stakeholders are limited;
- Inadequate consultation or integration of local stakeholders (especially the poor) into the design and implementation of ecosystem management programmes;
- Capacity development to maximise sustainable ecosystem management for poverty is highly required for research providers and users.

D2 – Capacity development strategy for research providers

It is crucial that research providers have developed a conceptual framework of ecosystems, ecosystem services and poverty, and have access to necesary information and possess the skills/tools/resources to conduct research. The following capacity development strategy for research providers is arranged in order of importance for change.

Institutional skills and tools on ecosystem management and poverty alleviation

Capacity building at research institute level should be targeted on the research knowledge, skills and tools needed to tackle the key research needs identified in Section C. This could be built up through funded research programmes and professional training and workshops. Research institutions at a local level should be given a higher priority to become involved in research programmes and improve their data collection and analytical capacity. A curriculum of ecosystem management and poverty alleviation should be developed and established at universities.

Increase financial investment in targeted research priorities

Increased national or international financial investment should target the research prioritised in Section C. A sound and practical financial support programme should compliment China's 11th Five Year Programme in Science and Technology. The research programme should favour research proposals with multi-disciplinary teams and cross-sectoral approaches, and promote research networks that include different research organisations from environment and poverty sectors. A monitoring plan should be included in the research programme in order to assess knowledge and behavioural changes that result from the research activities, and to ensure the most effective use of funds. Regional and international cooperation should be encouraged to tackle global issues such as climate change and invasive alien species. Public-private partnerships should be explored to diversify and expand financial resources.

Training of individual researchers

Education and training of researchers is needed through national and international exchange programmes and international placement of individuals in order to build expertise and capacity in China. Particular examples are in ecosystem analysis, climate change adaptation, valuation of ecosystem services, PES, proposal writing and project management. Training opportunities should be closely linked with funded research programmes to ensure that newly-trained individuals can then use and develop further their research skills and train other researchers (i.e. the 'training of trainers').

Encourage the linkages of natural science with social science, particularly policy research

Ecosystem management and poverty alleviation involves research across the natural and social science spectrum. The need within China for better integration of natural and social science, particularly political research, is a key issue. Research proposals with multi-disciplinary teams and cross-sectoral approaches should be encouraged and ranked higher priority for financial support.

Strengthen partnerships, communication and information-sharing among national and international level research providers

There is a strong need for capacity building and strengthening of research partnerships. Building research platforms and networks through funded research programmes can engage and facilitate this cross-sectoral participatory approach. Time should be allocated for research organisations to participate and develop full research proposal, and thus help to build trust and cooperation from the

start of a project. In addition, thematic workshops to bring different research organisations together should be used to encourage and facilitate communication and information sharing among research providers. Some of the underlying skills, such as capacity in global climate modeling, require international partnerships. In other cases, China can also contribute to international knowledge level.

Improve access to information, and management and dissemination of information

Access to high quality and authoritative information is a constraint for research providers wishing to conduct research focused in China. Improved information access, either to international sources or to Chinese information will improve the capability of research providers in tackling of research problems in ecosystem services and poverty alleviation. Information-sharing mechanisms, such as knowledge networks, wiki and list-servers, should be encouraged. There is also a strong need for better information collection and compilation, management and dissemination (including translations of Chinese material into English for world-wide dissemination).

D3 – Capacity development strategy for research users

Ideally, research users should effectively uptake research results into decision making and implement this in the field under an appropriate policy and legal framework with feed-back to research providers, and thus form a smooth knowledge generation flow (Annex 14). The following capacity development strategy for research users is arranged in an order of importance for change.

Target the financial support to the poor at lower levels in ecosystem degradation areas

A challenge for poverty alleviation in China is that the remaining poor are now much more difficult to reach. They mostly live in remote mountainous and grassland areas with extremely limited access to arable farmland that is often subject to severe environmental degradation. China's striving for a more balanced development and for a harmonious society is a part of a global trend of a growing concern for equity in opportunities as opposed to equity in income. The financial support should be not only targeted to the poor village within the poor counties (Figure A1.2), but also outside the poor counties especially those who live in ecosystem degradation areas. It is very crucial to ensure that the financial support reach the real poor that they are intended for, with minimum loss during the process. Inequality issues such as gender and disability should be also considered in the process. The financial support should also tackle the most critical issues to maximize poverty alleviation, e.g. water irrigation system, clean drinking water, biomass technology transfer, village road constructions in remote mountain areas etc.

Integrate environmental protection with poverty alleviation strategy

The China's 11th Five Year Plan emphases on a more scientific and human-centred approach to development, that addresses growing inequalities, a circular economy with an efficiency of resource use, development of a resource-efficient society, assistance to poor farmers and improvement of natural environmental protection etc. Despite political recognition of poverty-environment relationships, few successful examples of how to address this linkage have been generated in practice. Economic growth is still a higher priority than the environment protection, especially at local level and in less developed areas. Cross-sectoral coordination on ecosystem management and poverty alleviation still needs to be strengthened under the State Council at national level. Lack of practical guidance and low level of understanding about development and environment linkages have led to unintended results. Furthermore, poor communication and coordination among local stakeholders should be improved to adopt an integrated approach to ecosystem management and poverty alleviation.

Build local capacity through wider knowledge dissemination and extension systems

The development of local capacity includes introduction of new knowledge of ecosystem management and poverty alleviation, and training of lower level professionals, local communities and farmers, especially in western China. Among many national/regional training programmes, a good example is the "Sunshine Programme – National Farmers and Migrant Workers Training Programme (2003-2010)" initiated by the Ministry of Agriculture and other five ministries, within which over 11 million farmers have been trained by the end of 2007. Extensions systems and rural information systems and services with innovative approaches (e.g. Participatory Learning, CoPs, use of ICT, Farmer Participatory Research and Training, Farmer Videos etc) should be explored to facilitate wider knowledge dissemination. Although internet is the major information source and very popular in China, exploration of other channels such as printed material in easily understood languages, and

audio-visual material should be undertaken, especially in areas with low or none internet connectivity. Partnerships between research users in eastern and western region of China, which are encouraged as a basic part of the current Western Development Strategy, should also be further underpinned.

Increase financial investment at local ecosystem sectors on priority issues

The State Environmental Protection Agency (SEPA) was recently promoted to full ministry status at the 11th National People's Congress in March 2008, which indicates a potential increase in financial investment by the central government. To promote political considerations on ecosystem management for poverty alleviation and influence important policies and strategies such as China Poverty Reduction Strategy, we also need to work closely with the less environment-oriented sectors such as Ministry of Finance, local governments, private sector and media agencies. A deliberated route plan should be developed to target these different audiences and identify particular allies and/or strong players to be influenced. It is important to show how sustainable ecosystem management will contribute to helping these sectors achieve their goals and China Poverty Reduction Strategy outcomes. In addition, financial investment should target more implementing agencies of ecosystem sectors at county and township levels, particularly in under-developed western China, to improve their equipment, and increase their training and human resource development activities.

Encourage participation of end users (e.g. the poor) in the local development planning process

Establishment of an interactive mechanism between local government, farmers and farmer associations is very critical for poverty alleviation. Poverty alleviation results are much more effective if the poor, farmer associations or local ecosystem managers participate in the planning, design, implementation, and monitoring of activities that affect them. Actually, China has made great advances in this aspect and the Office of the State Council Leading Group for Poverty Reduction through its village targeting, and participatory village development planning has been at the forefront of such innovations in China. However, this still remains to be a big challenge to implement across the country. The call for a harmonious society and a more equitable society in China's 11th Five Year Plan is a tremendous opportunity to practice this in a wider scale. Governmental officers should be trained on participatory methodology towards involving end users in development planning and decision making process.

Incorporate the value of ecosystem services in decision making

The value of ecosystem services is not well incorporated in decision making in China. The goods and services generated by natural resources are generally neglected in national statistics, so development agencies and national/local governments have often undervalued the potential role of ecosystem services to poverty reduction and economic growth. Public awareness campaign and wider debate across different stakeholders should be conducted to promote the value of ecosystem services.

Encourage participation of NGOs/CBOs and improve their capacity

A finding from the stakeholder interview is that environmental NGOs and community-based organisations (CBOs) are not engaged so much in ecosystem management and poverty alleviation process. Many of them underestimate the importance of National Poverty Reduction Strategy to their work and/or do not have appropriate skills (advocacy, social analysis, and macro and microeconomics). Audience-specific training should be provided with localised knowledge to these NGOs/CBOs to improve their capacity in this field. Inviting these grassroots organisations to workshops/meetings/field surveys and or research projects could also help them to play a more important role in ecosystem management and poverty alleviation.

Encourage participation of private sectors

The private sector, such as agricultural enterprises, is encouraged by the government to participate in poverty alleviation, and great successes have been made in this aspect. However, private sector participation in ecosystem management is a new and developing area in China, which should be further promoted. In addition to development of environmental infrastructure, the private sector could also contribute to education and training, technology transfer, policy formulation and public awareness.

Increase public awareness on ecosystem management and poverty alleviation

As public interest in environmental issues grows, public awareness and participation is very important for ecosystem management, especially PES. Publicity through multiple channels (e.g. information days, leaflets, promotion materials, press conferences, newspapers, TVs etc) should be mobilised to

increase public awareness on ecosystem management and poverty alleviation.

D4 – Cross-cutting capacity development strategy for research providers and users.

Establish an interactive cooperation mechanism between research providers and users

The complexity of ecosystem management and poverty alleviation requires participation of multi-stakeholders, widespread awareness-raising, understanding and learning, and capacity building at different levels. The need within China for better integration between natural sciences and social science, particularly policy research, as well as cross-sectoral and multidisciplinary participatory approaches have been recognised as a key challenge. Establishment of interactive and cooperation mechanism is strongly encouraged to bring research providers and users together to tackle the key issues. The interactive communication mechanisms should include stakeholder meetings, workshops, fora, consultation and discussion groups. Participatory approach to bring all the stakeholders together should be applied in the process.

Explore an innovative research-into-use system

Translation of research knowledge into practice is frequently articulated as a weakness of the Chinese system (Cook et al., 2007). Research that is undertaken through one vertical system (e.g. agriculture and forestry) may not be readily fed into broader policy debates and policy makers, or down to implementers and end users (especially the poor) across the sectors. New knowledge or findings need to be communicated more effectively–between research providers and users within the country. However, the old extension system in China is less effective with the rapid economic development and social change. An innovative "research into use" system and effective information system and services should be explored in accordance with China's New Village Construction Strategy. Knowledge management tools such as Communities of Practice (CoPs), participatory learning networks and ICT-based information systems are important elements to support capacity development activities.

Promote international collaboration on capacity building and technology transfer in third countries

With its rapid economic development and advancing research and technology, China is becoming more and more engaged in global development issues, particularly south-south collaboration with South-east Asian and African countries. Knowledge gained and lessons learned from China will also help better ecosystem management and poverty alleviation in other developing countries. Training, jointly established agricultural technology demonstration centres, technological assistance and scientific exchange are the main areas of cooperation. For example, China is in the process of helping African countries build 10 agricultural technology demonstration centers, establish 100 hospitals, train about 1500 African agricultural professionals and send 100 Chinese senior agricultural experts to Africa to help build their capacity. By joining forces with the international development community, China's outreaching programme in African countries will have a greater impact.

D5 – Priority recommendations on capacity development for research providers and users in China

Based on the above strategy analysis, we highly recommend the following top six integrated capacity development priority strategies for financial investment at the first instance.

- ***Awareness-raising Strategy:*** Advance research providers and users' awareness, knowledge, understanding, goals and values on ecosystem services and poverty alleviation, conduct action research studies aiming at generating new knowledge and better understanding of how ecosystem services may evolve, change and be managed in China;
- ***Impact Demonstration Strategy:*** Increase target-oriented financial investment in focused research priorities of ecosystem service and poverty alleviation, local ecosystem sectors and poor people at lower levels in ecosystem degradation areas to demonstrate impacts and encourage others to follow, and engage appropriate and efficient public and private partnership;
- ***Multiple Incentive Generating/Simulating Strategy:*** Encourage participation of end users (e.g. the poor) in the local development planning process, improve governmental officers'

understanding and adoption of participatory approach involving end users in their development planning and decision making process, simulating better incentives of end users, and explore a novel knowledge dissemination and extension system, aimed at better promotion and implementation of research results in the field by end users;

- ***Integrated Innovation Strategy:*** Improve understanding and knowledge of ecosystem services and poverty alleviation through multi disciplinary and cross-sectoral innovative research, encourage the linkages of natural science with social science and particularly policy research, and incorporate the values of ecosystem services into a integrated environmental protection and poverty alleviation strategy;
- ***Information Support Strategy:*** Establish an interactive cooperation mechanism between research providers and users, develop an innovative research-into-use system to strengthen partnerships, communications and information-sharing among national and international level research providers, and promote international collaboration on capacity building and technology transfer to disseminate Chinese experiences to third countries.
- ***Capacity Building Strategy:*** Build up capacity at national, institutional, regional and local level, develop a curriculum of ecosystem management and poverty alleviation at universities, provide training to individual researchers, and improve access to high quality and authoritative national or international information on ecosystem management and poverty alleviation.

Concluding Remarks

This section does not present the conclusions from this study, as the main findings are given in the Executive Summary and at the end of each main section. The aim of these concluding remarks is to convey a few messages and lessons learned by the project partners during their collaboration.

One major challenge for this situational analysis has been to locate information on ecosystem services and poverty alleviation (ESPA) in China. The published literature includes local studies and some national overviews relevant to ecosystem services, but this project found little publicly available information on poverty and very little analysis of rural livelihoods in relation to ecosystems. However, the project's Ningxia Hui case study shows that considerable relevant information is available at the provincial level and is used by government planners. Overall, this project consortium considers that it has captured the essence of the current knowledge of ecosystem services and drivers of change in China, and identified the main research issues concerning their role in the livelihoods of the poor.

To develop ESPA-relevant policies is made difficult by more than a lack of information, as it also requires being able to conceptually analyse the relationships between management of ecosystems and poverty in specific circumstances, which is a new area for research and policy-making. It is a major challenge to adopt a more holistic framework for research and decision-making, not only including ecological science for multiple ecosytem services but also socio-economic science for effective policies. The scale of this challenge to create multi-disciplinary research and policy teams should not be underestimated.

China has a great capacity for implementing major programmes for improving the environment and reducing poverty, often under the concept of 'ecological construction'. However, these programmes need to be designed with a more sophisticated consideration of their impact on ecosystem functioning and poverty vis-a-vis local conditions. For example, widespread promotion of tree planting and banning grazing are likely to be successful in areas with regular rainfall, but in more arid regions there is a significant risk of actually reducing the availability of water in the ecosystem and causing grassland degeneration over periods of 5 to 10 years. As part of improving local adaption and promoting success, there is a need for more monitoring of the ecosystem and social impacts of many Chinese government programmes. Such monitoring with local stakeholder participation would in turn provide the basis for more effective ESPA research and policy-making.

The government of China is continually developing its concepts, policies and capacity to achieve sustainable development and a 'harmonious society'. Examples of this include the concept of "conservation culture", payments for environmental services, and the upgrading of the State Environmental Protection Administration (SEPA) to a full Ministry in 2008. Reversing ecosystem degradation and reducing poverty are key priorities for the government, and this ESPA situation analysis has received great interest from government and academia in China. The challenge now is to further develop the understanding of ecosystem management for multiple services and poverty reduction, and to demonstrate this widely in the countryside of China. This will require institutions and individuals within government and the research community to jointly champion this approach.

In many ways this project has been a capacity-building exercise for all of the partners. The sheer size and diversity of China and the new topic of ESPA have made the situation analysis complex and demanding. All of the partners agree that the disciplinary diversity and international make-up of the consortium have generated interesting interactions and experiences, as well as challenges in learning new ways of working, resulting in the fostering of wonderful synergy and collaboration. As part of achieving the aims of ESPA, international networking and cooperation will harness more technical expertise and good experiences from other countries to help China better tackle this complex topic.